EXPIRATORY MUSCLE STRENGTH TRAINING IN PATIENTS WITH IDIOPATHIC PARKINSON'S DISEASE. EFFECTS ON PULMONARY ,COUGH AND SWALLOW FUNCTIONS

By

AHMAD FARIS SALEEM

A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF OOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

2005

ACKNOWLEDGMENTS

First and above all, all thanks be to Allah, the creator of humankind, Whose knowledge is beyond comparison and Whose mightiness is proved constantly in the modest discoveries of His creation.

Many people have contributed to the successful completion of this project. I am grateful for their efforts and dedications throughout its progress. I would like to thank my dissertation committee members (Dr. John Rosenbek, Dr. Christine Sapienza, Dr. Rahul Shrivastav, and Dr. Paul Davenport) for their time, effort, and guidance during the development, progress, and unfolding of this research. I would like to specifically convey my deepest feelings of gratitude to Dr. John Rosenbek and Dr. Christine Sapienza, whose dedication, patience, and support were truly invaluable to ensure the successful completion of this project and my Ph.D. program. Their great mentoring has positively impacted my life forever and helped me mature academically and personally.

I would like to also extend my gratitude to the members of the University of Florida Movement Disorders Center and to its co-director, Dr. Michael Okun, for generously sharing his knowledge, experience, and support to accomplish the objectives of this project. His assistance and coordination were also essential in recruiting the participants involved in this study and in patiently scoring the piles of motor exam videotapes. I am grateful for his dedication and assistance.

In addition, this project would not be possible without the help of students who volunteered their time and effort. I specially thank Michelle Troche, whose assistance in participants' recruitment, evaluation, and training was invaluable for the completion of this study. Additionally, I would like to thank Karen Wheeler, a lab colleague who gracefully donated her time and effort to ensure the reliability of swallow measurements.

Further, I am grateful for the insightful comments, critiques, and directions that the swallow research group at the Malcom Randall VA Medical Center provided. Their collective wisdom and knowledge were crucial to the development, progress and completion of this project.

Moreover, I would like to thank the Garson dissertation fellowship and the University of Florida Research Opportunity Fund for their financial support of parts of this project. Their financial help was crucial for its accomplishment.

Finally, I would like to extend my gratitude to my parents and my family for their continuous support and encouragement throughout my educational years. Their help, dedication, and love were of the utmost significance for all my work.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of Dissertation Presented to the Graduate School
of the University of Florida in Partial Fulfillment of the
Requirements for the Degree of Doctor of Philosophy

EXPIRATORY MUSCLE STRENGTH TRAINING IN PATIENTS WITH IDIOPATHIC PARKINSON S DISEASE. EFFECTS ON PULMONARY COUGH AND SWALLOW FUNCTIONS

By

Ahmad Faris Saleem

May 2005

Chair John C Rosenbek
Cochair Christine M Sapienza
Major Department Communication Sciences and Disorders

Respiratory dysfunction is a frequent comorbidity among patients with idiopathic Parkinson s disease (IPD). Respiratory muscles control both ventilatory and non-ventilatory functions and their strength reduction might cause serious consequences to these functions This study investigated the effects of an expiratory muscle strength training (EMST) program on the strength of the expiratory muscles and the effects of EMST on ventilatory (pulmonary) and non-ventilatory (pulmonary, cough and swallow) functions of the respiratory muscles in patients with IPD It further investigated the effects of antiparkinsonian medications on pulmonary and cough functions

Participants included 10 (4 females, 6 males) individuals with IPD of moderate clinical severity (Hoehn & Yahr II III) with an average age of 58 8 years. Respiratory measures included maximum expiratory pressure (MEP) forced expiratory volume in 1 second (FEV1), the ratio of FEV1 to forced vital capacity (FEV1/FVC), and maximum expiratory flow (MEF) Cough measures included inspiratory and compression phase

durations peak expiratory flow rate and amplitude and duration of the post peak plateau Swallowing measures included temporal measures of pharyngeal response, hyoid movements and velopharyngeal closure during swallowing of 5cc and 10cc of thin liquid and pudding boluses as well as displacement measures for hyoid superior and anterior movements In addition the total duration and number of swallows for a 3oz thin liquid, average penetration-aspiration (P-A) scores of different bolus sizes and consistencies and scores in the swallowing quality of life questionnaire (SWAL-QOL) were included.

EMST resulted in significant improvements in most pulmonary function measures (MEP, FEV1 MEF not FEV1/FVC), only cough inspiratory phase duration, and hyoid elevation displacement ratio and P A scores during swallowing Antiparkinsonian medications did not alter any of the pulmonary function measures but negatively affected the cough inspiratory phase duration and peak expiratory flow Males significantly outperformed females in most pulmonary (except FEV1/FVC) and cough (except compression phase duration) measures and the total SWAL-QOL score Females on the other hand significantly outperformed males in the measure of hyoid anterior movement displacement ratio during swallowing

This study was the first step towards exploring the efficacy of EMST in patients with IPD The lack of medication effect could lend support to the potential of non dopaminergic in addition to dopaminergic pathways involvement in the pathogeneses of respiratory and cough difficulties in patients with IPD These interactions are complex and require careful examination of their effects on the functions investigated in the current study

CHAPTER I
INRODUCTION AND LITERATURE REVIEW

Parkinson's Disease: Definition and Classifications

Parkinsonism refers to a general syndrome of movement, psychiatric, and/or cognitive disorders caused by the loss of dopaminergic neurons in the basal ganglia and brainstem (Cornford Chang & Miller 1995 Marsden, 1994). Based on their presumed etiology and clinical presentation, three general subtypes of Parkinsonism have been identified to include primary or idiopathic Parkinson's disease (previously known as "paralysis agitans"), secondary Parkinsonism (has an identifiable causal agent such as toxins drugs, or infections) and multiple heterogeneous system degeneration (Hoehn & Yahr 1967, Martilla 1983). Primary or idiopathic Parkinson's disease (IPD) the focus of this project is the type of Parkinsonism with no identifiable pathology that can be considered as its etiologic factor. Recently, three different phenotypic forms of IPD have been suggested. These phenotypes include tremor predominant, akinetic rigid, and postural instability/gait problems (Olanow & Koller 1998 2001). IPD can be further classified based on the level of disability into one of five stages using an arbitrary scale (Hoehn & Yahr 1967). This placement relates the patient's level of involvement to the impairment in their balance (or righting reflexes). It ranges from unilateral involvement (stage i) to stage V defined as the most severe level of clinical disability of confinement to bed or wheelchair (Table 1-1).

Table 1.1 Modified Hoehn & Yahr Clinical Severity Stages

Stage	Clinical Severity
0	No signs of disease
1	Unilateral disease.
1.5	Unilateral plus axial involvement.
2	Bilateral disease, without impairment of balance
2.5	Mild bilateral disease, with recovery on pull test.
3	Mild to moderate bilateral disease; some postural instability; physically independent.
4	Severe disability; still able to walk or stand unassisted
5	Wheelchair bound or bedridden unless aided

IPD results from the progressive neurodegeneration of the dopamine producing cells in the brainstem (DeLong, 1990; Martilla, 1983). Movement abnormalities dominate the signs and symptoms associated with IPD and include tremor, rigidity, bradykinesia (movement slowness), hypokinesia (movement reduction), akinesia (movement absence) and impaired postural reflexes (Marsden, 1994). These symptoms can affect, with variable degrees, many of the physiological functions under muscular control (e.g., walking, respiration, cough, swallowing). Consequently, various difficulties in respiration, cough, and swallow are frequently present in patients with IPD.

Respiratory Dysfunction in Patients with IPD

Respiratory dysfunction is frequently reported as a common comorbidity among patients with IPD (Gorell, Johnson, & Rybicki, 1994; Schiermeier, Schafer, Schafer, Greulich, & Schlafke, 2001; Shill & Stacy, 1998). In addition, aspiration pneumonia, a known respiratory complication, has the highest mortality risk ratio among all comorbidities in patients with IPD (Fernandez & Lapane, 2002; Hoehn & Yahr, 1967; Pepper & Goldstein, 1999; Singer, 1992). These respiratory impairments include reduced vital capacity (De La Torre, Mier, & Bosches, 1960; Izquierdo-Alonso, Jimenez-Jimenez, Cabrera-Valdivia, & Mansula-Lesmes, 1994; Neu, Connolly, Schwertley, Ladwig, & Brody, 1967), lower than normal values for maximal flow values (Hovestadt, Boggaard, Meerwaldt, Mache, & Sngt, 1989; Izquierdo-Alonso et al., 1994; Neu et al., 1967), and abnormal pattern of the flow volume curve (Hovestadt et al., 1989; Izquierdo-Alonso et al., 1994; Vincken, Gauthier, Dolfuss, Hanson, Darnnay, & Cosion, 1984). The cause for this respiratory dysfunction remains unclear and has been attributed to many factors including an obstructive disease that is caused by or coexists with IPD. In fact, Obenour

and colleagues (1972) contended that expiratory flow obstruction in patients with PD is caused by a coexisting chronic lung disease with increased airway resistance or decreased lung elastic recoil (Obenour, Stevens, Cohen, & McCutchen, 1972). However, Nett and colleagues (1967) found evidence that this obstructive nature was consistent with the neuromuscular dysfunction found in PD and attributed the expiratory flow obstruction to the mechanisms of akinetocholinesia, rigidity, or parasympathetic hyperactivity as they affect the respiratory muscles (Nett et al., 1967).

Although an airway obstruction is a widely accepted explanation for the commonly observed respiratory dysfunction in patients with IPD, another theory cannot be ignored. Karvonen, Saarelainen, and Nieminen (1994) contended that the apparent upper airway obstruction in neuromuscular diseases might be an erroneous interpretation of underlying weak expiratory muscles. This weakness in expiratory muscles can lead to reduced maximal expiratory pressure and peak expiratory flow rate values as well as an increased residual volume value. This collection of signs often misleads to the erroneous interpretation of an airway obstruction although the resistance to air flow and the specific conduction are generally normal.

Both maximum expiratory (MEP) and inspiratory (MIP) pressures, known indices of expiratory and inspiratory muscle strength, have been found to be reduced in patients with IPD when compared to reference values (Bugaard, Hovestadt, Meerwaldt, Meche, & Stigt, 1989; De Bruin, De Brum, Lees, & Pride, 1993; Hovestadt et al., 1989; Weiner, Inzelberg, Davidovich, Nisipeanu, Magadle, Berar-Yanay, & Carasso, 2002). In addition, Bogaard and colleagues (1989) found worse values of MEPs and MIPs in patients with IPD with increased clinical severity. However, Tzelepis and colleagues

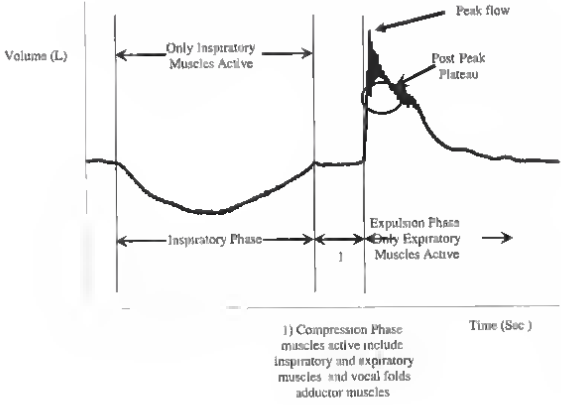
reported MIP values in a milder group of patients with IPD that are comparable to age matched controls (Tzelepis McCool, Friedman & Hoppin 1988)

The respiratory muscles are involved in other behaviors which serve motor or no ventilatory function such as coughing, sneezing vomiting swallowing and speaking The reduced respiratory muscle strength in patients with IPD might cause some serious consequences to these non ventilatory functions. Therefore, the activities of the respiratory muscles amid performing these behaviors as well as the possible effects of their rehabilitation are worth exploring Thus improving the strength of the respiratory muscle has the potential to improve ventilatory and non ventilatory functions Nonetheless some of these behaviors are more relevant to the purpose of this study than others. Accordingly the activities of the respiratory muscles during coughing and swallowing the effects of IPD on these functions, and their rehabilitative potential will be discussed.

Cough Physiology and Respiratory Muscle Activity

Cough is a protective airway reflex in which an attempt is made to remove substances from the upper (larynx) or lower (trachea and bronchi) airways using high airflow velocities generated by forced expiration (Shannon, Bolser & Lindsey 1997) The reflexive nature of this behavior indicates the presence of sensory stimuli that can elicit (through neural connections) rapid motor responses The stimulation of some receptors therefore, is carried through sensory neurons whose excitation incurs the activation of motor neurons resulting in the production of cough The motor pattern of each cough consists of three consecutive phases (see Figure 1-1) inspiration

Figure 1-1 A cough airflow waveform.



compression and expulsion (Leith, Butler, Sheddou & Brain, 1986). The activity of the respiratory muscles during each of these phases is complex and requires a control mechanism for the commencement and termination of the cough.

During the inspiratory phase of the cough, inspiratory muscles and vocal fold abductors simultaneously contract. The contraction of the inspiratory muscles continues in the next phase (compression) but they are combined with the contraction of the abdominal expiratory muscles and the laryngeal adductor muscles (and relaxation of the abductors). Finally, expulsion results from opening the glottis (by relaxing the adductors and contracting the abductors), that is followed by the termination of inspiratory muscle activities with the persistent activity of the abdominal expiratory muscles resulting in the defining high airflow velocity of the cough (Shannon et al., 1997).

The reflexive pattern of each cough is initiated by stimulating sensory receptors of the larynx, trachea, or bronchi. Two kinds of receptors have been associated with the stimulation of cough: rapidly adapting receptors (RAR) and pulmonary stretch receptors. Both of these kinds are present in the trachea and bronchi, whereas only RAR are present in the larynx (Coleridge & Coleridge, 1994; Karlsson, Sant'Ambrogio, & Widdicombe, 1988). C-fiber afferents carry these stimulations from the larynx (through the internal superior laryngeal nerve, SLN), trachea and bronchi (through vagal afferents) to the caudal nucleus tractus solitarius (NTS), which projects to central respiratory areas in the brainstem (including DRG, cVRG, and rVRG) to potentially alter their activation.

Swallowing: Physiology and Neural Control

Swallowing is another non-ventilatory function that the respiratory muscles are involved in. It refers to "the entire act of deglutition from placement of food in the mouth

through the oral pharyngeal and esophageal stages of the swallow until the material enters the stomach through the gastroesophageal junction (Logemann, 1998, p. 3). Physiologically a swallow could be divided into four phases, oral preparatory, oral, pharyngeal, and esophageal. Although some variations exist between different swallows the smooth sequential transition of the bolus among these phases is critical for its safe delivery to the stomach. This smooth transition is provided by an intricate neuromuscular control system that controls and coordinates the activities of different muscles involved in each of the swallowing phases. Understanding the physiological objectives of each phase and the neuromuscular mechanism involved in each of them is crucial for appreciating the physiologic and neuromuscular coordination that occurs between the two vital acts of swallowing and respiration.

The oral preparatory phase of the swallow "prepares" the material placed into the oral cavity by transforming it to a consistency ready for swallowing. The oral preparatory phase of swallowing starts with recognizing the material approaching or laying in the oral cavity as food and the sensory perception of its volume and viscosity. Various manipulations of the food take place in this phase (including mastication), with the end result of collecting and holding the food into a cohesive, or semicohesive, bolus of a size ready to be propelled posteriorly (Logemann, 1998). During these manipulations constant peripheral sensory feedback is necessary to track the location and readiness of the bolus as well as to prevent any injuries to the parts of the oral cavity (Lowe, 1980). Throughout this phase the respiratory airway is open and breathing is continued through the nasal cavity (Logemann, 1998).

During the oral phase of swallowing, the bolus is propelled backwards by the tongue. This is achieved by the tongue midline sequentially squeezing the bolus against the hard palate (Kahrilas, Lin, Logemann, Ergun, & Facchini, 1993). The tongue tip and its sides participate in this act by sealing off other potential outlets for the bolus by tightly attaching to the alveolar ridge. The pressure the tongue applies to the bolus to propel it posteriorly depends on its viscosity: with thicker food requiring more pressure (Reimers-Neils, Logemann, & Larson, 1994). The respiratory airways remain open during the oral phase of swallowing, allowing for nasal breathing to take place. When the bolus head reaches an arbitrary point where the mandible crosses the tongue base, it activates receptors (especially deep proprioceptive) at the base of the tongue and the oropharynx. These activations are carried to the brainstem (especially, nucleus tractus solitarius – NTS) and cortex via the VII, IX, X, and XI cranial nerve. The NTS passes this activation onto the nucleus ambiguous, which coordinates the termination of the oral phase of swallowing and the initiation (triggering) of the pharyngeal swallow pattern in a smooth manner that no pausing of the posterior bolus movement is observed. To do this, the nucleus ambiguous relies on a pool of cranial motor neurons that includes the V, VII, IX, X, and XII cranial nerves (Logemann, 1998).

When the pharyngeal swallow is triggered, a pattern of movement of several oral, pharyngeal and laryngeal structures takes place. This pattern is characterized by the closure of the velopharyngeal port by the superior and posterior movement of the velum, the upward and forward movement of the hyoid bone and the larynx, contributing to the airway entrance closure and the cricopharyngeal muscle opening (respectively), the closure of the larynx by the sequential closure of the true vocal folds, the laryngeal

vestibule (by inferior anterior and medial movement of the arytenoid cartilages, and the laryngeal elevation and anterior movement) and the epiglottis. The pharyngeal swallow also includes movements that result in the opening of the upper esophageal sphincter (i.e., cricopharyngeal sphincter), and delivering the bolus into the pharynx and, ultimately, into the esophagus. This action involves sliding the bolus over a ramp-shaped tongue base followed by the propulsion of the bolus into the esophagus by the simultaneous action of tongue base retraction and progressive contraction of the pharyngeal wall. The cricopharyngeal opening is achieved by a number of sequential muscular activities. These activities start by the relaxation of the cricopharyngeal muscle, followed shortly (approximately 0.1 seconds) by its forceful opening as a result of the hyolaryngeal superior and anterior movement. The passing of the bolus head through the sphincter widens its opening and allows for the bolus to pass into the esophagus. As soon as the bolus tail clears through the sphincter, the larynx is lowered and tension in the cricopharyngeal muscle is restored. Entering the esophagus, the bolus is pushed down by the progressive, sequential contraction (peristalsis) of the esophageal muscles until it reaches the lower esophageal sphincter, which opens to empty the bolus into the stomach (Logemann, 1998).

A central pattern generator (CPG) for the rhythmic and sequential production of swallowing has been established (Carpenter, 1989; Doty, 1968; Jean, 1990) to control the drive of the motoneurons involved. The CPG neurons are concentrated into the dorsal (thus called the dorsal swallowing group, DSG) and ventral (thus called the ventral swallowing group, VSG) areas of the medulla. Swallowing neurons have been located in the dorsal medulla within the nucleus tractus solitarius (NTS) and neighboring reticular

formation and in the ventrolateral medulla (VLM) just superior to the nucleus ambiguus (Jean & Car 1979, Kessler & Jean 1985). The results of CPG activities are carried out through a pool of motoneurons including the trigeminal (V), facial (VII) glossopharyngeal (IX) vagus (X), hypoglossal (XII) and motoneurons in high cervical levels (C1 – C3) of the spinal cord (Carpenter 1989, Doty, 1968, Miller, 1982).

Some level of functional organization exists within this neural network (Jean, Car, & Kessler 1997). According to the contemporary model of the swallowing neural control the primary sensory relay area in the NTS (i.e., DSG) is involved, nonetheless, in the generation of the swallowing motor pattern and driving the neurons of the VSG. The VSG, in turn, is involved in the dissemination of this drive to the motor neurons involved in the swallowing act (e.g. V, VII, IX, X and XII) and the coordination of their activities (Jean, 1990, Jean et al., 1997). Due to its intimate relationship with the motor neurons, the VSG is conceived to be involved in the switching and the coordination of their activities during different motor behaviors (e.g., swallowing, respiration). This view is supported by electrophysiological (Amri & Car, 1988, Amri, Car, & Jean 1984, Amri, Car, & Roman, 1990, Ezure, Oku, & Tanaka 1993), lesioning (Jean & Car, 1979; Kessler & Jean 1985) activity recording (Miller, 1982) pattern induction (Bieger 1991, Kessler & Jean 1991, Kessler, Cherkaoui, Catalin, & Jean, 1990) and activation latency experiments (Jean & Car, 1979).

Although much is yet to be learned about the internal mechanisms of the CPG in controlling and generating the swallowing motor pattern, the evidence currently available suggests that the inherent properties of the neurons in this network and their interaction to be critical in shaping the overall activities of the CPG. Jean (1984) suggested the

presence of a neural network within the NTS (DSG) to control the pattern of neuronal firing. This internal network is believed to be formed by a chain of neurons with a rostrocaudal organization. In which the proximal-distal innervation of the swallowing canal is controlled respectively by neurons in the rostrocaudal axis of the NTS internal network. Activation of neurons in the rostral end of this chain starts the sequential contraction of the swallowing muscles by successive excitatory synapses with other neurons in the network. Excitation of rostral neurons in the network (controlling proximal swallow muscles) also results in the unleash of a successive inhibitory pattern of caudal neurons controlling distal swallowing muscles. This internal mechanism of the CPG is supported by the findings of the NTS neurons intrinsic properties (Grillner & Wallen Dale Brodin Buchanan & Hill 1987 Tell & Bradley, 1994 Tell & Jean 1991 1993). Specifically some NTS neurons discharge is delayed when polarized due to their possession of an early transient outward potassium current (I_{KA}). Some other NTS neurons possess low-threshold activated calcium currents ($I_{T(Ca)}$) involved in the re excitation of neurons previously inhibited (postinhibitory rebound). In addition stimulation of NTS neurons with NMDA receptors produces a "pacemaker like" activity likely to be involved in burst generation of the CPG (Jean Car, & Kessler 1997).

Swallowing and Respiration. Functional and Neural Interactions

Swallowing and respiration are not exclusively reciprocal physiological acts. In fact respiration is only interrupted during the pharyngeal stage of the swallow, while it is maintained in the other swallowing phases (i.e., oral, oral preparatory, and esophageal). This brief interruption of the breathing mechanism is referred to as the apneic period and

reflects the closure of the airway, and the temporary suspension of chest wall movement (Logemann 1998)

Swallowing and respiration strongly interact both functionally and centrally The occurrence of swallowing in a specific phase of the respiratory cycle is species-dependent In cats and humans, swallowing occurs predominantly during expiration whereas it occurs predominantly during inspiration in dogs, rabbits and monkeys (Dick, Oku, Romaniuk, & Chernack, 1993 Martin, Logemann Shaker & Dodds 1994 Nishino Yonezawa, & Honda 1985) Whether swallowing occurred during inspiration or expiration no significant change in the ventilation level is observed (Issa & Porostocky, 1994) Minor differences, however are observed in the duration and depth of the interrupted respiratory cycle If swallowing occurs during expiration the expiratory phase of the cycle is extended with no change in the tidal volume In the case of swallowing during inspiration however the inspiratory phase is abruptly terminated for the swallow to take place This is followed by an abbreviated expiratory phase Swallowing during inspiration therefore, results in a reduction of both the tidal volume and the duration of the respiratory cycle In either case (inspiratory or expiratory swallow) an increase in the tidal volume of the breath cycle immediately following the swallow is observed (Nishino et al , 1985) If more than one swallow is attempted in a sequence the associated breathing pattern depends highly on the swallow rhythm (regular or irregular) and its frequency Repeated swallowing (rhythmic or irrhythmic) is associated with faster and deeper post swallow breaths Irregular swallowing rhythm is associated with a breathing pattern that is inconsistent in frequency and depth (tidal volume) When slow regular repeated swallows are attempted, the breathing pattern

remains unchanged, with slow regular deep breaths observed. Faster repeated swallows are associated with faster breathing frequency that is reduced in amplitude (tidal volume). Complete suspension of the respiratory cycle is observed, however, when very fast regularly repeated swallows are produced (Jean et al., 1997). In addition, there is evidence to support that for muscles common in respiration and swallowing, a shift in their swallowing pattern to a respiratory movement pattern is observed if a respiratory distress (e.g., asphyxia) is sensed (Doty & Bosma, 1956).

Centrally, evidence exists that some neurons firing during respiration are also active during swallowing (Sumi, 1963). This phenomenon of "neuron flexibility" (Doty, 1968) is supported by the findings that a common pool of motoneurons and interneurons exists to support the activities of the respiratory/swallowing muscles during both functions. Common motoneurons whose function is shared between the two functions include the IX, X, and XI cranial nerves (Larson, Yajima, & Ko, 1994; Sumi, 1969). The two CPGs for the two functions (i.e., respiration and swallowing) probably interact through their shared interneurons (Gestreau, Milano, Bianchi, & Grelot, 1996; Kessler, 1993; Larson et al., 1994; Oku, Tanaka, & Ezure, 1994; Yajima & Larson, 1993) to generate the motor pattern (through common and uncommon motoneurons) of the function at hand. This view is supported by evidence that a cellular basis exists for neurons in the NTS to perform multiple tasks (Tell & Jean, 1991, 1993). Depending on their inputs, neurons of the NTS can have several firing patterns (i.e., tonic, rhythmic burst, and beating like firing), suggesting the potential of their involvement in multiple functions (Dickinson & Moulins, 1992; Jean et al., 1997).

Effects of Bolus Consistency Variation on Swallow Physiology

Many studies have examined the effects of bolus consistency variation on the quantitative features of the oral and pharyngeal phases of swallowing. Indeed, increases of some muscles activation level and duration as measured by surface electromyography (sEMG) were noted. Specifically, both submental (suprahyoid) and infrahyoid sEMG recordings were reported to increase in amplitude (Dantas & Dodds, 1990; Ding, Logemann, Larson, & Rademaker, 2003) and duration (Ding et al., 2003) with increases in bolus consistency. In addition, increases of some temporal measures of swallowing were also reported as a result of increases in consistency. These included increases in the durations of the oral transit time (Dantas, Kern, Massey, Dodds, Kahrilas, Brasseur, Cook, & Lang, 1990), base of the tongue contact to the posterior pharyngeal wall (Lazarus, Logemann, Rademaker, Kahrilas, Pajak, Lazar, & Halper, 1993), pharyngeal transit time (Bulow, Olsson, & Ekberg, 2003; Dantas et al., 1990), pharyngeal peristalsis (Dantas et al., 1990), and upper esophageal sphincter opening (Dantas et al., 1990; Lazarus et al., 1993). Finally, increased bolus consistency was found to increase pharyngeal retention (Bulow et al., 2003) and reduce penetration and aspiration of the airway (Bulow et al., 2003; Kuhlemeier, Palmer, & Rosenberg, 2001). However, bolus consistency changes did not alter the manometric results of the pharynx or the upper esophageal sphincter (Meier-Ewert, van Herwaarden, Gideon, Castell, Achem, & Castell, 2001), nor did it alter the swallow associated breathing pattern (Preiksaitis & Mills, 1996).

Effects of Bolus Volume Variation on Swallow Physiology

Many studies investigated the effects of bolus volume variation on the temporal and displacement measures of swallowing physiology as well as its effects on swallow muscle activation and the swallow associated breathing pattern. Increases in the bolus volume were found to increase the temporal measures of laryngeal elevation (Kahrilas & Logemann, 1993) and closure (Lazarus et al., 1993) as well as the temporal measures of opened upper esophageal sphincter (Dantas & Dodds 1990, Lazarus et al., 1993, Dantas et al. 1990) and total swallow durations (Kahrilas & Logemann, 1993) while they were found to decrease the duration of the base of the tongue contact to the posterior pharyngeal wall (Lazarus et al., 1993). However changes in bolus volume did not change the temporal measures of oral transit (Dantas & Dodds, 1990) and pharyngeal transit (Dantas & Dodds 1990, Kahrilas et al., 1993). Conflicting results were reported for the effects of bolus volume variation on the temporal measures of hyoid movement and pharyngeal response. While Kahrilas and Logemann (1993) observed significant increase of hyoid excursion duration with increased bolus volume, Dantas and Dodds, (1990) showed no change of the hyoid movement duration. Similarly, Bisch, Logemann, Rademaker, Kahrilas, and Lazarus (1994) reported significant reductions in pharyngeal response time with increased bolus volume while Lazarus et al. (1993) observed no difference.

Swallow structures displacements were also reported to be affected with bolus size variations. Indeed, increases in bolus volume were reported to cause increases in hyoid superior and anterior movements (Dodds, Man, Cook, Kahrilas, Stewart, & Kern, 1988) as well as increases in laryngeal chamber dimensions (Kahrilas, Lin, Chen, &

Logemann 1996) and upper esophageal sphincter opening diameter (Dantas et al., 1990; Leonard, Kendall, McKenzie, Goncalves & Walker 2000). Further, increased bolus volume was reported to cause increased pharyngeal constriction (Leonard et al., 2000).

Results of sEMG studies of the effects of bolus volume variations on swallow muscle activations showed increased amplitudes and durations of submental (suprahyoid) and infrahyoid recordings with increased bolus volume (Dantas & Dodds 1990). However, in a recent study utilizing contact electromyography Perlman and colleagues found no change among their recordings of muscle activations during swallowing of different bolus volumes (Perlman, Palmer, McCulloch & Vandaele 1999). Nonetheless, volume-dependent changes were observed for the temporal relationships of muscle activations. Indeed, the interval between the onset of laryngeal muscle activity (thyroarytenoid and interarytenoid) and of pharyngeal muscle firing patterns (superior pharyngeal constrictor onset and cricopharyngeus offset) decreased as bolus volume increased (Perlman et al., 1999). Finally, the effects of bolus volume on swallow-associated breathing pattern were also investigated. Results suggested that although the swallow respiratory phase relationship was unaltered by bolus volume, longer apneic periods and swallow-associated respiratory cycle were observed (Hiss, Treole, & Stuart, 2001; Preiksaitis, Mayrand, Robins, & Diamant 1992).

Effects of IPD on Neuromuscular Functions

The intricate, sequential pattern of muscle movements required for the completion of the cough and swallow functions might be disrupted in patients with IPD as the neuromuscular control system that controls and coordinates these activities might be affected. The progressive neurodegeneration of the dopamine producing cells in the

substantia nigra, a group of cells in the brainstem. In patients with IPD disturbs the intricate balance in the basal ganglia motor circuit. The behavioral manifestations of this disturbance may be explained based on the cumulative effects that the defective component may have on deregulating the cohesive and balanced interaction within the circuit components as well as their interactions with other neural circuits and structures. According to Alexander, DeLong, and Strick (1986), the basal ganglia are viewed as a family of functionally segregated circuits that originate from different cortical areas, projecting to separate areas of the basal ganglia and thalamus. Thalamic efferents in turn, terminate on the same areas of the frontal cortex from which the circuit originated. At least five such basal ganglia-thalamocortical circuits have been identified to run through similar areas of the basal ganglia (i.e., striatum-globus pallidus, and substantia nigra pars reticulata), yet their segregation is maintained throughout these circuitry components. These five basal ganglia circuits include, as described by Alexander et al (1986), motor, oculomotor, dorsolateral prefrontal, lateral orbitofrontal, and anterior cingulate circuits (see Figure 1-2). Of these circuits, the motor circuit has probably received the most attention as it is implicated in different movement (hypo- and hyperkinetic) disorders including Parkinson's disease.

In its contemporary view, the basal ganglia-thalamocortical motor circuit (see Figure 1-3) takes origin from the sensory and motor areas of the cortex and projects to the putamen (the motor part of the striatum). The circuit also includes motor areas in the globus pallidus, substantia nigra, and thalamus before projecting back to the motor cortical areas. Two pathways organize the putaminal output to direct the activity of the

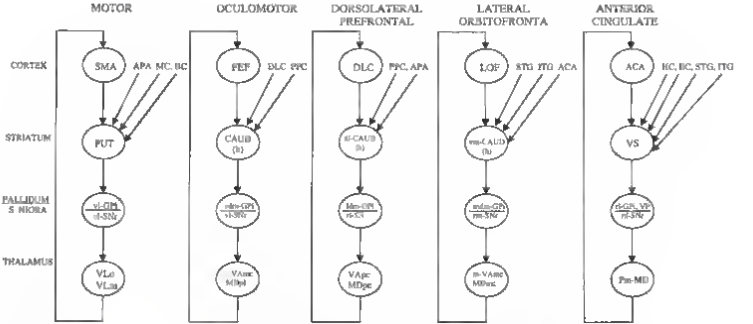


Figure 1 2 The thalmocortical circuits of the basal ganglia (adapted from Alexander et al ,1986)
Abbreviations ACA anterior cingulate area, APA arcuate premotor area, CAUD caudate, (b) body, (h) head, DLC dorsolateral prefrontal cortex EC entorhinal cortex FEF frontal eye fields, GPi internal segment of globus pallidus HC hippocampal cortex, ITG inferior temporal gyrus LOF lateral orbitofrontal cortex MC motor cortex MDpl medialis dorsalis pars parvalamellaris MDmc medialis dorsalis pars magnocellularis MDpc medialis dorsalis pars parvocellularis PPC posterior parietal cortex PUT putamen, SC somatosensory cortex SMA supplementary motor area, SNr substantia nigra pars reticulata, STG superior temporal gyrus, VAmc ventralis anterior pars magnocellularis, VApc ventralis anterior pars parvocellularis, VLm ventralis lateralis pars medialis VLo ventralis lateralis pars oralis VP ventral palhdum VS ventral striatum cl- caudolateral, cdm- caudal dorsomedial, dl- dorsolateral, l- lateral ldm- lateral dorsomedial m- medial, mdm- medial dorsomedial pm posteromedial, rd- rostrodorsal, rm- rostromedial, vm- ventromedial, vl- ventrolateral

two major outputs of the basal ganglia (i.e., substantia nigra pars reticulata and globus pallidus pars interna). Differences between the pathways arise from the type of striatal dopaminergic receptors activated (i.e., D1 or D2) and whether or not the putaminal nigral/pallidal connection is monosynaptic. In the first "direct" pathway, dopaminergic inputs from the substantia nigra pars compacta (SNc) induce excitatory response of the putaminal D1 receptors, whose neurons have monosynaptic GABAergic (gamma aminobutyric acid) inhibitory projections to the globus pallidus pars interna (GPi) and the substantia nigra pars reticulata (SNr). On the other hand, nigral dopaminergic inputs in the "indirect" pathway induce an inhibitory effect on D2 receptors of putaminal neurons, which project (GABAergic inhibitory) to the external segment of the globus pallidus (GPe). The GPe has direct (GABAergic inhibitory) and indirect (via the subthalamic nucleus - STN) projections to the GPi and the SNr. The GPe also projects to the nucleus reticularis of the thalamus (NR). The connection between the GPe and STN is reciprocal. All pallidal projections are inhibitory and utilize GABAergic neurons. The projections of the STN, on the other hand, are excitatory and utilize glutaminergic neurons.

The GPi and SNr project to different areas of the motor thalamus as well as the midbrain tegmentum and superior colliculus. All of GPi and SNr projections are GABAergic and inhibitory with projections from the GPi supplying the ventralis lateralis pars oralis (VLo) and ventralis anterior (VA) areas of the thalamus which, in turn, project to the supplementary motor area (SMA) and premotor area of the cortex, respectively, to complete the basal ganglia-thalamocortical circuit. Projections from the SNr supply the ventralis anterior magnocellularis (VAmc) area of the thalamus, which, in turn, projects

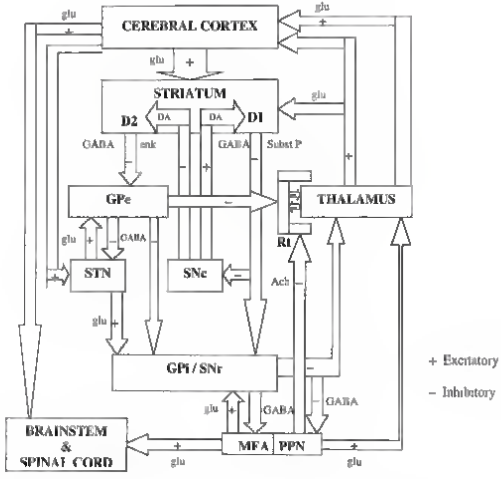


Figure1 3 The normal basal ganglia-thalamocortical motor circuit (adapted from Vitek (1997))

Abbreviations GPe globus pallidus external segment, SNc substantia nigra, pars compacta STN subthalamic nucleus Gpi globus pallidus internal segment, SNr substantia nigra, pars reticulata Rt Reticular thalamic nucleus PPN pedunculopontine nucleus, MEA, midbrain extrapyramida area Ach acetylcholine glu glutamate, GABA gammaaminobutyric acid enk enkephalin subst P substance P, DA dopamine D1 dopamine receptor type 1, D2 dopamine receptor type 2

to the prefrontal cortex. Both the thalamocortical and corticostriatal projections are glutaminergic and excitatory.

In IPD, dopamine deprivation of neurons in the putamen affects the motor circuit output via both the direct and indirect pathways to the GPi and SNr. In the indirect pathway, striatal dopamine deprivation results in the excessive inhibition of the GPe. Reduction in the activity of the GPe releases the STN from its inhibition. The STN, in turn, overly excites the GPi/SNr complex to inhibit the thalamocortical excitatory connection. In addition, the GPi and SNr are released from striatal inhibition exerted by the direct pathway and GPe of the indirect pathway. The consequent extra inhibition of thalamocortical and brainstem outputs (i.e., pedunculopontine nucleus and midbrain extrapyramidal area) has been suggested to account for the motor signs associated with IPD (DeLong, 1990; Vitek, 1997).

These changes in the motor circuit behavior can affect the production of movement necessary for respiration, cough and swallow. In general, IPD can affect movement production by causing difficulties in advance programming and accessing of movement programs (Benecdetti, Rothwell, Thompson, & Hallett, 2001), changes in motor unit recruitment and behavior (Glendinning & Enoka, 1994), reductions in the net muscular force generated (Corcos, Chen, Quinn, McAuley, & Rothwell, 1996), and impairments in the coordination within muscle groups (Johnson, Kipnis, Lee, Loewenson, & Ebner, 1991). These resultant changes can have serious sequelae for the functions of cough and swallow.

Cough in patients with IPD

Cough in patients with IPD was investigated by two groups of researchers Involvement of both the sensory and motor component of coughing was reported. Fantana, Pantaleo Lavorini Benvenuti and Gangemi (1998) found reduced electromyographic (EMG) activities of the abdominal muscles during voluntary and reflexive cough in patients with IPD as compared to controls In addition patients exhibited lower rate of rise of abdominal EMG activities They concluded that a central neural mechanism might have caused the noted impairments in the processes of motor unit recruitment and the increase in frequency discharge Ebihara et al (2003), on the other hand suggested that while patients in the "early" (Hoehn & Yahr II HI) stages of IPD exhibit motoric impairments in cough production patients in the "advanced" (Hoehn & Yahr IV V) stages suffer impairments in both the motoric and sensory component The effect of Parkinsonian medications on cough function was not investigated by either group and remains to be determined.

Swallowing in patients with IPD

Swallowing disorders (dysphagias) are a known complication of IPD with their presence reported in as high as 95% of patients (Calne Shaw, Spiers, & Stern 1970, Eadie & Tyrer, 1965a, Logemann Blonsky & Boshes 1975 Silbiger, Pikielney & Donner, 1967) Impairments in all phases of the swallowing process (oral preparatory oral transit, pharyngeal and esophageal phases) have been reported in patients with IPD (Logemann 1998) These impairments are usually complex and may be the result of changes in both striated muscles (under dopaminergic control) and smooth muscles

(under autonomic control) of the alimentary tract (Lieberman Horowitz, Redmond Pachter Lieberman & Leibowitz 1980 Morrell, 1992)

Dysphagia in general may cause the life-threatening condition of aspiration pneumonia Aspiration pneumonia a known respiratory complication is reported as the leading cause of death in patients with PD (Fernandez & Lapane, 2002, Gorell et al 1994, Hoehn & Yahr 1967 Schiemeier et al 2001 Shill & Stacy, 1998, Singer, 1992) Robbins Logemann and Kirshner (1986) attributed aspiration pneumonia in patients with PD to the impaired muscular control of oral pharyngeal and laryngeal structures leading to disorders of oral and pharyngeal phases of swallowing

The oral preparatory phase of swallowing in patients with PD is reported to be delayed and inefficient with deficient mastication (Athlin Norberg Axelsson Moller & Nordstrom 1989 Bushmann Bomeyer Leeker & Perlmutter 1989, Donner & Stiliger 1966 Eadie & Tyrer 1965b, Karlsson Persson & Johnels 1992 Leopold & Kagel, 1996) impaired lingual mobility (Blonsky Logemann Boshes & Fisher 1975 Bushmann et al., 1989 Leopold & Kagel, 1996 Robbins Logemann & Kirschner 1986) and slow and limited mandibular excursion (Calne et al., 1970 Karlsson et al 1992 Leopold & Kagel 1996) Leopold and Kagel (1996) also found mastication to be hesitant with absence of the normal rotary movements

The oral transit stage of swallowing is also impaired and is characterized as slow (Blonsky et al , 1975) with repetitive lingual pumping (Bushmann et al., 1989, Robbins et al 1986) hesitancy in initiating the swallow (Bushmann et al 1989) and piecemeal deglutition (Blonsky et al., 1975, Bushmann et al 1989, Leopold & Kagel 1996 Robbins et al , 1986) Blonsky et al (1975) explained this lingual pumping activity as

failed attempts to propel the bolus due to a blockage of the normal bolus trajectory as a result of prolonged posterior hyoid elevation. Finally, posterior bolus leakage was also observed in some patients with IPD prior to oral transit initiation (Leopold & Kagel, 1996).

Some controversy exists for the involvement of the pharyngeal stage of swallowing in patients with IPD. A group of researchers, Caine et al. (1970), reported little or no involvement of this stage. In addition, the findings of Nagaya, Kachi, Yamada, and Igata (1998) suggested that the movement durations of pharyngeal structures in patients with IPD are comparable to those of elderly control subjects. Nonetheless, most investigators report significant impairments in this stage including delayed contraction, reduced force of contraction, bolus retention or residue in the valleculae and pyriform sinuses, slow vertical laryngeal elevation, and laryngeal aspiration (Bird, Woodward, Gibson, Phyland, & Fonda, 1994; Bushman et al., 1989; Leopold & Kagel, 1997; Robbins et al., 1986). Furthermore, deficient epiglottic positioning and range of motion, cricopharyngeus and pharyngeal constrictor dysfunction were all observed in patients with IPD (Leopold & Kagel, 1997).

Esophageal abnormalities are also common among patients with IPD and include inefficient primary esophageal peristalsis resulting in delayed bolus transport and elicitation of tertiary contractions (Bassotti et al., 1998; Castell et al., 2001; Leopold & Kagel, 1997). Delayed opening of the lower esophageal sphincter (LES) and gastroesophageal reflux was reported in most patients with IPD (Leopold & Kagel, 1997).

Many underlying mechanisms have been proposed to account for these swallowing difficulties. Difficulties of the volitional oral stage have been attributed to bradykinesia or rigidity of the lingual (Athlin et al, 1989; Lieberman et al., 1990; Morrell, 1992) velar (Robbins et al., 1986) and mandibular (Karlsson et al., 1992; Leopold & Kagel, 1996) musculature. Presence of cellular pathologies (i.e., Lewy bodies) in some brainstem nuclei including the dorsal motor nucleus of the vagus and the medullary reticular formation (Den Hartog Jager & Bethlem, 1960; Forno, 1981) was speculated to contribute for impairments in the pharyngeal (Robbins et al., 1986) and esophageal (Eadie & Tyrer, 1965b) stages of swallowing in patients with IPD. In addition, deficits in the way the basal ganglia influence sensory components of the trigeminal system were also suggested for sensorimotor abnormalities of oropharyngeal swallowing (Labuszewski & Lidsky, 1979). In essence, the gating effects of the basal ganglia on the trigeminal sensory inputs are under-activated and sensory signals have limited access to effector motor regions (Schneider, Diamond, & Markham, 1986). Difficulties of the non volitional pharyngeal stage have also been attributed to delayed activation of nuclei in the lower brainstem (Robbins et al., 1986).

Interventions for Functional Rehabilitation in Patients with IPD

These sequelae of IPD on the functions of respiration, cough, and swallow are serious and warrant the quest for physiologically valid and efficacious interventions. In general, both pharmacological and behavioral interventions can be postulated for the treatment of these functions. Conceivably, pharmacological treatments can restore the level of dopamine (DA) in the basal ganglia whereas behavioral interventions attempt to regain or compensate for the impaired functions.

Pharmacological treatments aim to either enhance (DA agonists) or replace (Levodopa) the diminishing amounts of DA in the brains of patients with IPD. Other medications are used to block dopamine metabolism, including catechol-O methyl transferase (COMT) and monoamine oxidase B (MAO B) inhibitors or its re uptake (amantadine) (Caine 1994 Tolosa & Valldeoriola 1994) Several studies investigated the effects that pharmacological treatments have on the functions of respiration and swallowing in patients with IPD To date however no studies have investigated the effects of these medications on the impaired cough function in patients with IPD

Physiological Mechanisms for Improved Motor System Function with Pharmacological Interventions in IPD

Antiparkinsonian medications can conceivably, improve movement production in patients with IPD by improving its programming and execution levels Execution of voluntary muscular contractions was associated with cortically initiated rhythmic activities (Brown 1997 McAuley, Rothwell, & Marsden, 1997, Halliday Conway Farmer, & Rosenberg 1998) These rhythmic activities of the motor cortex were found to be reduced in patients with IPD (Brown 1997, Brown, Salenius Rothwell & Hari, 1998) In a recent study, Salenius and colleagues showed that levodopa restored these rhythmic activities in the motor cortex (Salenius, Avikainen, Kaakkola, Hari, & Brown, 2002) Specifically they showed that levodopa shifts the motor cortex synchronized activities to a more efficient pattern to recruit motor units. At the programming level, a recent study used electrophysiological and behavioral patterns to demonstrate that administration of antiparkinsonian medications restores the programming related activities in the brains of patients with IPD (Pattapposta, Pierelli, My, Mostarda, Del Monte, Parisi, Serrao, Morocutti & Amabile, 2002)

Effects of Pharmacological Interventions in IPD on Pulmonary Function

The effects of antiparkinsonian medications on the pulmonary function of patients with IPD are still unclear. Conflicting results dominate the studies reported thus far. While Obenour et al. (1972) failed to detect a respiratory function improvement following levodopa treatment, Nakano and colleagues found significant improvement of respiratory function following levodopa administration as compared to placebo (Nakano, Bass, & Tyler, 1972). In addition, Vincken, Damany, and Costa (1989) reported reversibility of a pattern of UAO following levodopa intake as demonstrated by a sequence of flow-volume curves in a single subject with IPD. Finally, administration of a dopamine agonist (i.e., apomorphine) was reported to result in improvements of respiratory function in patients with IPD (De Bruin et al., 1993). Specifically, studies found improvements in peak expiratory flow (PEF; Nakano et al., 1972, Herer, Arnulf, & Housset, 2001), forced expiratory volume in the first second (FEV1; Nakano et al., 1972, Herer et al., 2001), forced vital capacity (FVC, Nakano et al., 1972), and total lung capacity (Nakano et al., 1972) following levodopa treatment.

Effects of Pharmacological Interventions in IPD on Respiratory Muscle Strength

The effects of antiparkinsonian medications on the maximum expiratory and inspiratory pressures (MEP and MIP, respectively) of patients with IPD were reported only by two studies, one investigated the effect of levodopa intake (Weiner et al., 2002) and the other investigated the effect of dopamine agonist (apomorphine) intake (De Bruin et al., 1993). While a nonsignificant trend toward an increase of MEP and MIP was found by Weiner and colleagues following levodopa intake, De Bruin and his colleagues found a significant improvement of MEP following apomorphine intake.

Effects of Pharmacological Interventions to IPD on Swallow Function

Marked relief with levodopa of the cardinal motor signs of the limbs in patients with IPD is not associated with a similar trend of the swallowing symptoms. Some anecdotal reports allude to improvements of swallowing abnormalities in a minority of their patients (Cooley & Donner, 1966; Cotzias, Papavasiliou, & Gellene, 1969; Paulson & Tafrate, 1970). Several studies, however, evaluated the effects of levodopa on swallowing abnormalities in patients with IPD. Calne and colleagues failed to find a positive effect of levodopa on the dysphagia of patients with IPD (Calne et al., 1970). In contrast, Bushmann and colleagues showed that levodopa improves some aspects of pharyngeal function in 40% of their patients (Bushmann et al., 1989). This may suggest the involvement of non-dopaminergic pathways, in addition to the dopaminergic pathways, in the pathogenesis of swallowing abnormalities observed in patients with IPD.

One of the purposes of this project was to investigate the effects of pharmacological treatment on the respiratory and cough functions in patients with IPD. Conceivably, improvements in the programming and execution levels of the movements responsible for respiration and cough are possible following exposure to antiparkinsonian medications. Therefore, a better respiratory and cough performance can be expected after antiparkinsonian medication intake as compared to before their intake.

Behavioral Interventions for Functional Rehabilitation in IPD

Attempts to improve the functions impaired in IPD utilizing behavioral treatments have focused on either achieving or compensating for the function lost. Accordingly, a symptomatic approach has been adopted for the rehabilitation of patients with IPD with

varying success rate. For the functions of respiration cough and swallow, rehabilitation efforts are yet to prove their efficacy

In general, respiratory function rehabilitation has focused on improving the strength endurance and efficiency of the muscle function (Köseoğlu & Tomruk 2001) Early respiratory strength training programs (e g—deep breathing exercises, abdominal muscle exercises and abdominal weights) did not provide an adequate load to the respiratory muscles resulting in their limitation to show significant gains of their functional outcome. Contemporary respiratory strength training programs utilize the use of devices that allow targeting of specific muscle groups with challenging loads These respiratory training devices implement one of two respiratory strength training techniques, resistance or pressure-threshold training. Differences between the two techniques arise from the respiratory parameter they employ Resistance training uses devices that employ air flow resistance to increase respiratory muscle strength (Bach et al., 1993) Pressure-threshold training on the other hand requires the build up of a sufficient lung pressure to overcome the "pressure threshold" necessary to open an adjustable one-way valve In pressure threshold training modification of the airflow mechanics is not allowed as a stable airflow is required, adding to the specificity of this technique to the respiratory muscles targeted (Belman 1993)

Regarding swallowing no single therapeutic behavioral technique has yet been proven efficacious in eliminating the cohort of swallowing abnormalities in patients with IPD Rather swallowing abnormalities are managed in a case-by-case basis with the aim to improve a specific single dysfunctional element in the swallow sequence (Yorkston, Miller, & Strand, 2004) Alterations to diet texture and increasing sensory input were

also suggested to have the potential of facilitating swallowing function in patients with IPD (Yorkston et al., 2004). A recent study, however, investigated the effects of a well-known voice rehabilitation technique, the Lee Silverman Voice Treatment (LSVT)®, in improving the swallowing difficulties in patients with IPD (Sharkawi et al., 2002). Improvements in the neuromuscular control of the entire upper aerodigestive tract were proposed for the reductions in swallowing mobility disorders observed. The LSVT utilizes the exercise principles of intensity and specificity to improve the activity of targeted muscles. Similarly, these principles are utilized in a respiratory muscle strengthening program targeting the expiratory muscles known as the expiratory muscle strength training (EMST) program.

Expiratory Muscle Strength Training (EMST)

EMST utilizes a pressure threshold device with a consistent pressure load to expiration. EMST is a rehabilitative program that is both intensive and physiologically specific, targeting the expiratory muscle group. Some of the expiratory muscles are skeletal muscles (namely, the abdominal and internal intercostal muscles) and share the same structural and functional characteristics of the limb skeletal muscles. Structurally, expiratory muscles have similar histochemical presentation as that of the limb muscles. Both abdominal and internal intercostal muscles are composed of an approximately equal distribution of type I (slow-oxidative) and type II (fast-twitch) muscle fibers, a finding common to skeletal limb muscles (Mizuno, 1991). This structural similarity between expiratory and limb muscles suggests that both muscle groups utilize similar metabolic processes for the production of energy necessary for muscle contraction. Thus, a strength

training program for the expiratory muscles is conceivable if it utilizes the same principles used to strengthen the limb muscles

The strength of the skeletal muscles was found to increase after they are exposed to strength training programs (McArdle, Katch, & Katch, 1996; Sale, 1988). Muscle strength training refers to the process of increasing the targeted muscle's performance by increasing its capacity to produce energy as a result of its regular exposure to a physiological load (Powers & Howley, 2001). These changes in muscle performance and capacity are referred to as the training effect and are physiologically realized as a result of a challenging and specific training program. A physiologically challenging load is that in which the muscle is exercised at more than its habitual level. Such a challenging load can be produced by increasing the intensity, duration, or frequency of the targeted muscle's exercise. In addition to realize an optimum training effect, the strength training program has to be specific for the targeted muscle and activity (Powers & Howley, 2001). Therefore, the information gained from studying the principles of limb muscle strength training paradigms were used to develop the EMST program for conditioning the expiratory muscles (Chiara, Martin, Sapienza, & Bolser, 2003; Sapienza, 2002; Sapienza, Davenport, & Martin, 2002; Sapienza, Hoffman, Ruddy, Davenport, Martin, & Lehman, 2001).

The improvements in strength realized in skeletal muscles after exposure to a training program are attributed to many underlying physiological mechanisms that vary depending on the period of the conditioning program (Enoka, 1988; Montani & deVries, 1980; Sale, 1987). Early strength changes are attributed to improvements in muscle recruitment and de-recruitment of antagonistic muscles and neural adaptations. Neural

adaptations result in rapid strength gain as a result of increased motor unit excitability, enhanced coordination, and more efficient motor programming. Muscular adaptation is suggested to contribute to the strength improvements occurring at later stages of the strength training program. This muscular adaptation includes dramatic muscle diameter increases, as verified by CT imaging (Sale, 1987) and alterations in muscle fiber type composition from a fast to a slower fiber type (i.e., IIb to IIa, Adams, 1993). Greater functional gain is achieved with loads of 70-90% of the maximum load for the duration of 30-60 seconds and the frequency of 3-4 times in 3-4 days per week (Casaburi, 1994; Glassman, 1998).

In essence, EMST works by increasing the strength of the expiratory muscles that results in the production of a higher expiratory drive and higher expiratory lung pressure. This effect was realized in many populations including healthy individuals (Baker, 2003), 'high risk' vocal performers (Sapienza et al., 2001), individuals playing brass and wind instruments (Sapienza et al., 2002), patients with multiple sclerosis (Chiara et al., 2003; Gosselink, Kovacs, Ketelar, Carton, & Decramer, 2000; Smeltzer, Lavietes, & Cook, 1996), and patients with spinal cord injury (Sapienza, 2002). In addition to improvements in the physiologic measure of lung pressure, patients of these populations reported a reduction in exertional dyspnea following their treatment. Furthermore, the contraction of the expiratory muscles is important for the production of the high airflow necessary for cough production. Preliminary results from a recent study (Baker et al., 2002) provide evidence that cough production can be improved with EMST in healthy adults (ages 18-50 years old).

Potential Underlying Physiological Mechanisms for the Therapeutic Effects of EMST

Several central and peripheral mechanisms could be postulated to support the potential benefits of EMST in patients with IPD. A respiratory muscle strength training program could help restore the performance of targeted respiratory muscles by reducing their reaction times, reducing the co-contraction of their antagonistic muscles, and improving their strength. Generally, reduced reaction time is evident in elderly individuals as a result of exercise (Hart, 1981). In patients with IPD, this could translate to improvements in bradykinetic symptoms.

Strength training in general can further improve motor performance by reducing the coactivation of antagonistic muscles. Indeed, Gibberd and colleagues found that strength training programs have been effective in reducing this antagonistic coactivation in young individuals (Gibberd, Page, Spencer, Kinnear, & Hawksworth, 1981). This finding suggests that a respiratory strength training program can improve the motor performance of its targeted muscles by reducing the interference effect caused by the coactivation of antagonistic muscles, a common finding among patients with IPD (Glendinning & Enoka, 1994).

Both expiratory and inspiratory muscle performances are significantly reduced in patients with IPD (Weiner et al., 2002). Reports also exist that patients with IPD can improve the skeletal muscle strength of their limbs with a strength training program (Scandalis, Bosak, Berliner, Helman, & Wells, 2001). A respiratory muscle strength training program, therefore, could help restore the strength of targeted respiratory muscles and improve their performance.

Centrally two main mechanisms can be postulated to underlie the potential benefits of EMST in patients with IPD These include the changes of the cortical drive as a result of exercise and/or L-dopa administration as well as the potential effects of training in stimulating the neuroplasticity mechanisms in the brain

The effects of exercise on the molecular and functional activities of the healthy brain were documented At the molecular level, exercise was found to change the monoamine neurotransmitters levels in the brain (Heyes, Garnett & Coates 1985 MacRae, Spirduso Cartee, Farrar, & Wilcox, 1987 Speciale Miller McMillan & German 1986) Specifically, levels of dopamine in the brain were found to be increased following both acute and chronic levels of exercise While acute bouts of exercise were shown to result in a marked increase of the dopamine level in the striatum (Speciale et al , 1986), chronic exercise was shown to increase levels of dopamine synthesis and release in the whole brain (Heyes et al , 1985) Functionally temporary increase of motor evoked potential amplitudes during exercise was noted in healthy subjects (Brasil-Neto Cohen, & Hallett, 1994)

Conservably several underlying mechanisms could be postulated for the potential improvements of the specific functions of respiration cough and swallow as a result of EMST Increased strength of the expiratory muscles can translate to improvements in maximum expiratory pressure (MEP) Improvements in MEP as a result of EMST may result in improvements in the expiratory muscle forced activities needed for pulmonary function tests Specifically increases in the forced expiratory volume in 1 second (FEV1) the ratio of FEV1 to the forced vital capacity (FEV1/FVC), and the peak expiratory flow (PEF) may be observed in patients with IPD following exposure to

EMST. During cough, increases in the maximum expiratory flow rate and the post-peak plateau amplitude and duration may be observed as the expiratory muscles ability for forceful and sustained activation is improved. This improvement can also result in decreases of the compression phase duration. It is hypothesized that this reduction in compression phase duration will result from faster achievement of sufficient airflow for cough production following EMST, thus reducing the time needed to compress the vocal folds within the larynx for the development of cough force. Finally, improvements of the expiratory muscle activity may result in shortening of the cough inspiratory phase duration as the expiratory muscles require less air volume to deliver the required air flow rate to the expulsion phase.

Several underlying mechanisms could be hypothesized for the potential improvement in the swallow motor activations as a result of EMST. The increased activation of the lingual and oropharyngeal sensory receptors by the high airflow generated during EMST could result in increased activation of the nucleus tractus solitarius (NTS) and, in turn, the nucleus ambiguous and its associated motor units. This increased activation of these motor units can result in improved activation of the pharyngeal swallow pattern and its musculature. Specifically, this can be observed as improved motor response to afferent information (e.g., bolus), resulting in faster activation of the pharyngeal swallow, better activation of the velar, pharyngeal and laryngeal musculature. In essence, this has the potential of reducing the movement durations of these muscles during swallowing as well as increasing their displacement.

Another possible underlying mechanism for the potential improvement in swallow function utilizes the effects of changes in lung volume on upper airway musculature

Specifically, increased lung volume (used during EMST) was reported to cause increased activation of the levator veli palatini muscle (LVP, the main muscle of palatal movement) and the lateral cricoarytenoid muscle (LCA, a laryngeal adductor muscle) (Koizumi, Kogo & Matsuya, 1996). This can have the potential of improving velar elevation. Further, increased activation of the LCA has the potential of improving laryngeal closure during both swallowing and coughing and may result in the possible prevention or reduction of aspiration.

In addition, forced expiration can have the potential of improving the activities of some intrinsic and extrinsic laryngeal muscles. Specifically, Kuna and Vanoye (1994) showed that forced expiration is associated with increased activation of the laryngeal adductor muscles resulting in better laryngeal closure during both swallowing and coughing and the possible prevention or reduction of aspiration. Furthermore, expiration in general is associated with upward movement of the larynx (Fink & Demarest, 1978; Körkkö, 1998). This can have the potential of improving the activities of the suprahyoid muscles with possible reduction in hyoid movement durations during swallowing and possible prevention or reduction of aspiration.

Purpose

The purpose of this single group study was to investigate the effects of EMST on expiratory muscle strength in patients with moderate IPD (Hoehn & Yahr II-III) as measured by maximum expiratory pressure (MEP). This study also investigated the effects of improved expiratory muscle strength on the pulmonary and cough functions in patients with IPD. Further, this study aimed at investigating the effects that EMST would have on swallow functions (physiology and swallow related quality of life) in isolation.

from (OFF medications) pharmacological effects In addition this study investigated the effects of pharmacological treatment on the pulmonary and cough functions of patients with IPD by comparing their performance during the OFF (10 hours since last anti Parkinsonian medications intake) and ON (60 minutes since last medications intake) medication states

Measures of cough function included durations of the inspiratory phase (IPD), compression phase (CPD), and post peak plateau (PPPD) as well as the peak of the expiratory flow rate (PEFR) and the post peak plateau amplitude (PPPA) Swallowing measures included selected temporal and displacement measures of swallow physiology a measure of airway intrusion and a swallow related quality of life measure Temporal measures of swallowing physiology included pharyngeal response time (PRT), hyoid superior (HED) and anterior movement (HAMD) durations hyoid anterior motion response time (HAMRT) total hyoid movement duration (THMD) and closed velopharyngeal port duration (CVPD) of 5 and 10cc boluses and the total duration and number of sequential swallows required to clear a 3oz thin liquid bolus Displacement measures were utilized to measure the extent of swallowing-related movement of the hyoid bone The hyoid is generally described to have both superior and anterior movements during swallowing To measure the extent of these movements two relatively stable anatomical references were used, the inferior anterior edges of the external auditory meatus (EAM) and the third cervical vertebrae (C3) This double-point reference system was developed for this study because it was expected to be more valid than a single point reference system as it has the potential of better evaluating displacements in two planes. It is also expected to be more sensitive to changes in the

magnitude of displacement in these planes. The EAM is at a better anatomical position than C3 to measure superior changes in hyoid movement (figure 1-4) whereas C3 is at a better anatomical position than the EAM to measure changes of anterior hyoid movement (figure 1-5). Therefore, the ratio of the distance from the EAM to the hyoid at maximum elevation to the distance to the resting hyoid, the hyoid elevation displacement ratio (HEDR), was utilized to measure superior displacement of the hyoid. In addition, the ratio of the distance from C3 to the hyoid at maximum elevation to the distance when the hyoid is at its maximum anterior position during swallowing, the hyoid anterior motion displacement ratio (HAMDR), was utilized to measure anterior hyoid displacement during 5 and 10cc swallows.

A penetration aspiration (P-A) scale (Rosenbek, Robbins, Roecker, Coyle, & Wood, 1996) was utilized to measure relative intrusion of the airway during the swallows. Swallow related quality of life was measured using the Swallowing Quality of Life Questionnaire (SWAL-QOL; McHorney, Bricker, Kramer, Rosenbek, Robbins, Chignell, Logemann, & Clarke, 2000; McHorney, Bricker, Rabbins, Kramer, Rosenbek, & Chignell, 2000).

Figure 1-4 Hyoid Elevation Displacement Ratio (HEDR)

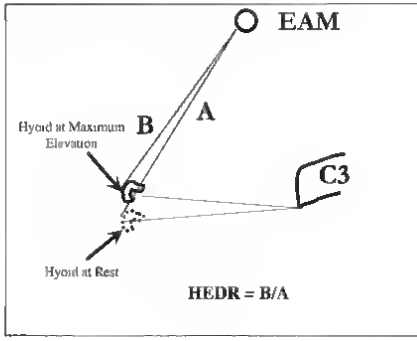
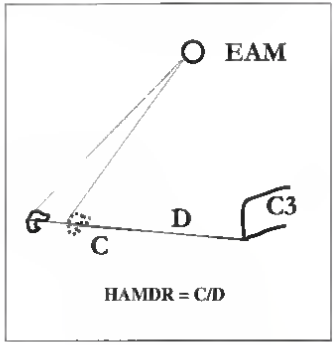


Figure 1-5 Hyoid Anterior Motion Displacement Ratio (HAMDR)



Hypotheses

Hypothesis 1

The maximal strength of the expiratory muscles can be increased in patients with IPD when exposed to a short term respiratory training program. Increased strength of the expiratory muscles will translate to improvements in maximum expiratory pressure (MEP). Higher measures of MEP will be observed during measurements made in the middle of the antiparkinsonian medication cycle (ON Medications) as compared to measurements made at the end of the antiparkinsonian medication cycle (OFF medications).

Hypothesis 2

Improvements in MEP as a result of EMST will translate to improvements in pulmonary function tests. Specifically, increases in the forced expiratory volume in 1 second (FEV1), the ratio of FEV1 to the forced vital capacity (FEV1/FVC), and the maximum expiratory flow (MEF) will be observed in patients with IPD following exposure to EMST. Higher measures of pulmonary function will be observed during the ON medication state as compared to measurements made during the OFF medication state.

Hypothesis 3

Improvements in MEP as a result of EMST in patients with IPD will translate to increases in the peak expiratory flow rate, post-peak plateau amplitude and duration. In addition, decreases of the inspiratory and compression phase duration during voluntary cough production will be observed. Greater measures of cough function will be observed

during the ON medication state as compared to measurements made during the OFF medication state

Hypothesis 4

Improvements in expiratory flow rate in patients with IPD as a result of exposure to EMST will translate to improved motor function of the pharyngeal phase of swallowing. Specifically, patients will have reduced PRT, HED, HAMRT, HAMD, THMD, and CVPD, and increased HEDR and HAMDR during swallowing of 5 and 10cc thin liquid and pudding boluses following exposure to EMST. In addition, the total number and duration of 3oz thin liquid sequential swallows will be reduced. The average PA scores during and thin liquid and pudding swallows will be reduced as a better closure of the laryngeal opening will be expected following exposure to EMST. These changes of swallow function will translate to improvements in swallow-related quality of life, as measured by the SWAL-QOL.

Since increasing bolus size or having a thicker consistency is associated with longer swallow movement durations and greater hyoid movement displacements with increased demand on forced activity of the swallow muscles; a worse baseline measurement is hypothesized for 10cc and pudding boluses. However, these boluses are also hypothesized to have the biggest improvements after exposure to the EMST rehabilitative program.

The swallow function will only be evaluated during the OFF medication state as antiparkinsonian medications consistently failed to induce improvements in swallow function in previous studies (Bushmann et al., 1989; Calne et al., 1970). The OFF

medication state was chosen because it best represents the physiological changes caused by the disease process of IPD

CHAPTER 2
METHODOLOGY

Experimental Design

The design of this project was a prospective repeated measures design. The independent variables included medication status (OFF/ON), gender, and baseline (Pre 1/Pre 2/Post treatment). The dependent variables were MEP, FEV1, FEV1/FVC, MEF, IPD, CPD, PEF, PPPD, and PPPA. Dependent measures for examining swallow function included PRT, HED, HAMRT, HAMD, THMD, CVPD, P-A score, HEDR, and HAMDR measured for swallowing of 5cc and 10 boluses of thin liquid and pudding consistencies as well as total duration, average P-A scores, and number of 3oz thin liquid sequential swallows. In addition, the patient perception of swallowing difficulties was measured with the total scores of the SWAL-QOL. For swallowing measures, two other independent variables were included: bolus size (5cc, 10cc) and consistency (thin liquid, pudding).

Sample Size Determination

As suggested by Marks (2000), sample size calculations were carried out. Calculations utilized maximum expiratory pressure (MEP) as the primary dependent variable. The standard deviation of MEP, σ, was determined from the range of MEP measurements obtained from the current study. The range was 111.2, yielding a σ of 27.8. The smallest clinical significant difference, or bound on error, between the average of MEP scores before EMST and their average after EMST was determined to be 25% of

the average baseline MEP Since the mean MEP was measured at 101 2, the bound on error (B) value was calculated and yielded a 25 3 minimum significant difference Using the obtained values of B and σ, a value for DELTA can be calculated DELTA is determined using the formula DELTA = B/σ Using that formula DELTA was determined at 0 910 As the significance level (α) and power of the test were predetermined at 0 05 and 80% respectively, a sample size determination could be carried out Using the table provided in Marks (2000), the number of participants needed for this study was ten Therefore 10 participants were recruited for this study

Recruitment and Selection

An approval to conduct this study was obtained from the University of Florida Health Science Center Institutional Review Board was obtained (IRB# 154-2003) Participants were recruited from patients visiting the University of Florida Movement Disorders Clinic in Gainesville, Florida.

Inclusion Criteria

Participants were included in this study if they meet the following criteria.

1 Age between 35 and 70 years

2 Diagnosis of tremor predominant idiopathic Parkinson's disease by a movement disorders neurologist

3 Moderate clinical disability level (II III, Hoehn & Yahr, 1967)

Exclusion Criteria

Participants were excluded from this study if they reported manifested, or had a positive history of

1 Other neurological disorders

2 Gastrointestinal disease.

3 Gastro-esophageal surgery

4 Head and neck cancer

5 History of breathing disorders or diseases (e g. Asthma, chronic obstructive pulmonary disease (COPD))

6 Untreated hypertension

7 Heart disease

8 History of smoking in the last five years

9 Failing the screening test of pulmonary functions (e g. FEV1/FVC < 75%)

10 Difficulty in complying to the training protocol due to neuropsychological dysfunction (e g. severe depression)

Measures

This study included a 7-week experimental protocol for each participant. Measures of respiration, cough, and swallowing were obtained prior to and after completion of EMST. The first two weeks and the last week of the protocol were devoted to baseline data collection sessions. Two baseline data collection sessions were conducted prior to starting the EMST and one session after. During each of these baseline data collection sessions, measures of respiration and cough were obtained twice, once while the participants were during the end of their drug cycle (OFF, 12 hours post last drug intake) and once while the participants were in the middle of their drug cycle (ON, 60 minutes after drug intake). Swallowing measures, however, were obtained only twice for each participant throughout the protocol, once during the second baseline pre-treatment OFF medication state and once during the post-treatment OFF medication state. The swallow

function were only evaluated during the OFF medication state as antiparkinsonian medications have failed to consistently induce improvements in swallow function in previous studies (Bushmann et al., 1989, Calne et al., 1970). The OFF medication state was chosen because it best represents the physiological changes caused by the disease process of IPD.

During each baseline session, the general motor function of the participant was examined using the United Parkinson's Disease Rating Scale (UPDRS-M) administered and video-recorded by a clinician trained by a movement disorders neurologist. Participants were examined twice during each baseline, once OFF medications and once ON medications. These videotaped motor examinations were later presented at random to, and scored by, a movement disorders neurologist who was blinded to the participant's training phase and medication status. Rigidity, however, was assessed by the examining clinician since its scoring is based on the clinician's tactile perception of the participant's muscle tone.

Random presentation of general motor, respiratory, and cough function tasks was continued for all participants to control for the effects of participant fatigue on these functions.

Pulmonary Measures

1. Maximum Expiratory Pressure. Expiratory muscle strength was measured as the maximum expiratory pressure (MEP) at the mouth. This measurement provides an indirect measure of the expiratory muscle strength. The measurement apparatus consisted of a mouthpiece connected to a pressure manometer (FLUKE 713-30G) by 50 cm of 2 mm i.d. tubing with a 14-gauge needle air leak. In order to measure MEP, the participant stood with his or her nose occluded with a nose

clip. After inhaling to total lung capacity, the participant placed his or her lips around the mouthpiece and blew out as forcefully as possible. Repeated measures were taken with a one to two minute rest between trials until three measurements are obtained within 5% of each other. The average of these three values was recorded.

2. Forced Vital Capacity (FVC), Forced Expiratory Volume at one second (FEV1), and maximum expiratory flow rate (MEF). The participants were asked to breathe in to their total lung capacity. The participants were then asked to blow out as forcefully as possible into a computerized spirometer (Spirovision 3+, FutureMed of America). FEV_1 is a measure of expiratory volume of the first second of expiration during the forced vital capacity maneuver.

Cough Measures

Cough measures were acquired from an airflow waveform obtained during a voluntary cough. The expiratory airflow waveforms were collected using a mouthpiece attached to a non-heated pneumotachograph (Hans Rudolf) with 30 cm of plastic tubing (3mm diameter). A differential pressure transducer (ML 140) with a pressure sensing range of ±12.5 cm H_2O was attached to the pneumotachograph. This attachment was fitted directly into the Power Lab/4SP data acquisition system (ADInstruments, ML750). Calculations of spirometric measures were provided by a software from ADInstruments (Chart 4 for Windows from ADInstrumens). Prior to collection of all cough measures, the pneumotachograph was calibrated by injecting a known value (3 liters) of air using a calibrated syringe. A calibration routine within Chart 4 for Windows software

(ADInstruments) was used to calculate volume and flow. All cough signals were recorded using the Chart 4 software.

To obtain an acceptable cough signal, the participants were seated with their nose occluded by a nose clip. The participant placed his or her lips around the mouthpiece and inhaled fully then produced three "strong" voluntary coughs into the pneumotachograph with a 30 second break between them. Measurements of cough were made using the Chart 4 software.

For each airflow waveform produced, five measurements were made (see Figure 1.1), inspiratory phase duration (IPD), compression phase duration (CPD), peak expiratory flow rate (PEFR), post peak plateau duration (PPPD), and post peak plateau amplitude (PPPA). IPD was defined as the time from the beginning to the end of the inspiratory phase marked by departure and returning of the airflow to 0 L/s respectively. PEFR (L/s) was defined as the peak flow rate (following an inspiratory period) measured from the expiratory flow waveform during a voluntary cough. CPD (in seconds) on the other hand, was defined as the time from the end of the inspiratory phase to the beginning of the expiratory phase. PPPD was defined as the time of sustained airflow that occurred after the peak expiratory flow. This was subjectively determined by observing the expiratory flow waveform. The initiation point for PPPD was marked as the time the flow became stable after the descent from its peak, while PPPD termination was marked as the final time point where the sustained stable flow ended prior to another descent in the expiratory flow rate. PPPA was defined as the amplitude of the plateau measured by the line of best fit of 6 randomly selected points to represent the amplitude.

Swallowing Measures

Swallowing measures were obtained from recordings of participants completing a Videofluoroscopic Swallowing Examination (VFSE). The VFSE included videotaping the subject in the radiologic suite (at Shands Hospital at the University of Florida) using standard fluoroscopic systems with remote monitor and a standard lateral view of the oropharynx. This lateral view allowed visualization of all critical oral and pharyngeal structures including jaw, lips, tongue, soft palate, larynx and pharynx. Each examination consisted of two trials swallowing 5cc and 10cc boluses of thin liquid barium (Liquid E-Z-Paque Barium Sulfate Suspension, 60% w/v, 41% w/w, Target Viscosity @ shear rate of 30 sec^{-1}, 4 cps, from E-Z-EM) and barium pudding (Varibar Pudding, Target Viscosity @ shear rate of 30 sec^{-1}, 6000 cps, from E-Z-EM), in addition to one, 3 oz thin liquid barium swallow presented at random.

The video recordings obtained in the VFSE were digitized using the Digital Swallow Workstation from KAY Elemetrics. The digitized recordings were analyzed at real time and frame by-frame to obtain accurate temporal measurements. Measures of swallowing function included:

- For 5 and 10cc swallows (2 times)
    - Penetration aspiration score. The score of each swallow on an 8 point Penetration Aspiration Scale (Rosenbek et al., 1996)
    - Pharyngeal response time (PRT), time (in msec) from the bolus passing the base of the tongue to the onset of hyoid elevation, indicating the onset of the pharyngeal phase of swallowing
    - Hyoid displacement durations

- Hyoid elevation duration (HED) time (in msec) from onset of hyoid elevation to the point it reaches its maximal elevation (superior movement)
- Hyoid anterior motion response time (HAMRT) time (in msec) from hyoid reaching maximum elevation to the onset of its anterior movement
- Hyoid anterior motion duration (HAMD) time (in msec) from onset of hyoid anterior movement to the point it reaches maximal anterior movement.
- Total hyoid movement duration (THMD) time from onset of hyoid elevation to its return to the resting position

o Hyoid displacement measures

- Hyoid elevation displacement ratio (HEDR) the ratio of the distance from the inferior anterior edge of the EAM to the most inferior point of the anterior edge of the hyoid at maximum elevation to that distance to the resting hyoid.
- Hyoid anterior motion displacement ratio (HAMDR) the ratio of the distance from the inferior anterior edge of C3 to the most inferior point of the anterior edge of the hyoid at maximum elevation to that distance when the hyoid is at its maximum anterior position during swallowing

o Velar movement

- Closed velopharyngeal port duration (CVPD) time (in msec) of velar contact with the posterior pharyngeal wall

- For 3oz thin liquid swallows:
    - Penetration-aspiration score The score of each swallow on an 8-point Penetration Aspiration Scale (Rosenbek et al , 1996)
    - Total duration of 3oz swallow time (in msec) from onset of bolus head posterior movement until bolus tail passes through UES into esophagus
    - Number of swallows required to clear a 3oz thin liquid
- Swallowing Quality of Life Measure Participants were asked to complete the Swallowing Quality of Life Questionnaire (SWAL-QOL) This newly standardized psychometric measures of swallowing-disorder related quality of life were developed from the patient s point of view (Appendix A) SWAL-QOL is a 44 item swallowing specific quality of life measure sampling 10 domains of quality of life It is sensitive to differences in severity of dysphagia and response to treatment. It provides the only reliable standardized psychometric measure of dysphagia related QOL extant.

Training Protocol

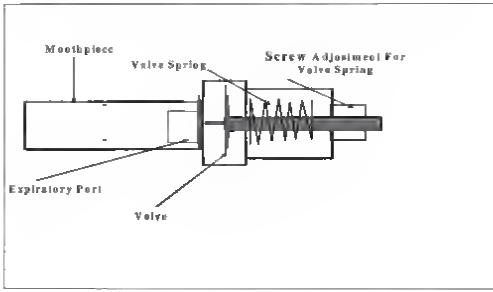
After completion of the two baseline sessions listed above each participant was provided with an expiratory pressure threshold trainer The expiratory pressure threshold trainer (Figure 2 1) consists of plexiglass tube with a variable tension spring controlling a "pop-off" valve The expiratory pressure threshold trainer provides a consistent pressure load on expiration Participants must overcome a threshold load by generating an expiratory pressure sufficient to open the expiratory spring-loaded valve The spring contained in this device is adjustable to allow for the required pressure threshold to be increased

This expiratory pressure threshold training device is a modification of a commercially available device manufactured by HealthScan Inc The modification of this device allows the pressure threshold to be set up to 150 cmH_2O The original device only allows pressure threshold settings up to 20 cmH_2O The higher pressure threshold settings are necessary to allow the threshold to be set at the challenging load of 75% of the participant s MEP

The training protocol for each participant lasted four weeks and consisted of five sets of five breaths five days per week with the pressure threshold set at 75% of the participant s MEP To insure compliance with the training protocol the initial training meeting between the clinician and each participant included training him/her on proper device handling procedures appropriate labial closure around the device's mouthpiece and air leak prevention techniques. To prevent possible air leak, the participant was trained to place his/her lips tightly around the device s mouthpiece while one of his/her hands held his/her cheeks firmly to prevent pocketing of air into the buccal cavity The participant was then instructed to blow as forcefully as possible into the device s mouthpiece from total lung capacity (TLC) The participants were trained to correctly identify successive valve opening trials by distinguishing a distinct audible sound as air passes through the device following the release of the valve

During the home-based training the participants independently followed the instructions given to them to complete the training sets To maintain a record of the participants compliance they were required to mark the completion of training sets on a log sheet (Appendix B) each week In addition a midweekly phone contact was maintained with each participant to ensure their compliance with the guidelines of the

Figure 2-1 A schematic drawing of the expiratory pressure threshold training device



training protocol

A weekly readjustment meeting was maintained with each participant. At that meeting the participant s MEP was measured in the same manner described earlier and the average value was used in the dataset The pressure threshold of the training device was then readjusted according to the newly measured average MEP value To ensure that the new load was achievable and appropriate the participant was required to complete the five training sets for that day while the clinician was in attendance Any concerns the participant had regarding the training program were addressed at that time

Training and readjustment meetings were held at a constant time (approximately 60 minutes after medication intake) in the participants regular medication cycle This was done to control for any possible interference that the pharmacological treatments might have had on the expiratory muscle strength measurements

Compliance

Participants were provided with written (Appendix B) and verbal instructions for the completion of the training protocol They marked the completion of training sets on a log sheet (Appendix C) each week

Statistical Analyses

Three multivariate repeated measures analyses of variance (MANOVA) and three repeated measures analyses of variance (ANOVA) were used to examine the effects of EMST on respiratory muscle strength cough swallow pulmonary function, total UPDRS-M and total SWAL-QOL scores Significant differences at alpha = 05 depicted in any of the MANOVA s were further explored using univariate comparisons of specific outcome variables All analyses were carried out using SAS software version 8 2.

In addition, the relationship between the change in MEP and other repiratory, cough and swallow function were investigated using tests of correlation Further inter- and intra-rater reliability were carried out on approximately 15% of the database A different examiner re-analyzed the data, providing the data needed to test for inter judge reliabilty of dependent variables To compare the results between examiners paired sample t tests and Pearson s tests of correlation were used The author repeated the analyses of 15% of the data sets to test for intra rater reliability Again paired sample t tests and Pearson's tests of correlation were used to test for differences among the values obtained.

CHAPTER 3
RESULTS

Ten participants were involved in this study. Their demographic information is summarized in Table 3-1. Four of these participants were females and six were males. Their age ranged from 54 to 68 years old (female *mean* = 57.50, *SD* = 2.89; male *mean* = 59.67, *SD* = 4.76). The average female clinical severity as determined by the modified Hoehn and Yahr clinical severity scale was 2.63 with a standard deviation of 0.25, whereas that average for males was 2.58 with a standard deviation of 0.49.

Maximum Expiratory Pressure (MEP)

A three-way repeated measures analysis of variance (ANOVA) was used to analyze the results of MEP as affected by gender (male, female), medication status (OFF, ON), and baseline (first baseline pre-treatment, second baseline pre-treatment, post-treatment baseline). Results of this ANOVA, presented in Table 3.2, revealed no significant three-way interaction between these three factors ($F_{2,120} = 0.31$, $p = 0.732$). Consequently, the two-way interactions were examined, and they manifested no significant interaction between the factors of gender and medication status ($F_{1,120} = 0.66$, $p = 0.419$) or between the factors of medication status and baseline ($F_{2,120} = 0.98$, $p = 0.377$). A significant two-way interaction was found, however, between the factors of gender and baseline ($F_{2,120} = 3.78$, $p = 0.026$). No significant difference was found in MEP between the OFF (*mean* = 106.93) and ON (*mean* = 108.19) levels of the main effect of medication status ($F_{1,120} = 0.17$, $p = 0.680$).

Table 3.1 Demographic information for participants included in the study

Participant	Gender	Age (yrs)	H&Y
1	M	58	2.5
2	F	57	2.5
3	M	57	3
4	M	61	2
5	F	61	3
6	F	54	2.5
7	M	60	2
8	M	54	3
9	F	58	2.5
10	M	68	3
Males Mean		59.67	2.58
Males SD		4.76	0.49
Females Mean		57.50	2.63
Females SD		2.89	0.25

Table 3 2 Results of the repeated measures ANOVA for MEP

Source	DF	Type I SS	Mean Square	F value	P value
Model	19	236571 670	12451 141	43 17	< 0 001
Medication	1	49 375	49 375	0 17	0 680
Baseline	2	25298 414	12649 207	43 85	< 0 001
Gender	1	37527 585	37527 585	130 10	< 0 001
Medication x Baseline	2	567 998	283 999	0 98	0 377
Gender x Medication	1	189 821	189 821	0 66	0 419
Gender x Baseline	2	2182 909	1091 455	3 78	0 026*
Gender x Medication x Baseline	2	180 112	90 056	0 31	0 732
Error	120	34613 941	288 450		
Corrected Total	139	271185 611			

* indicates that the mean difference is significant at $\alpha = 0.05$

The significant two way interaction between gender and baseline was submitted to further analysis with simple effect tests. Results of these tests presented in Table 3-3 and depicted in Figure 3-1, revealed that the MEPs measured for each gender were not significantly different during the two pre treatment baselines. Namely, MEPs measured for females during the first pre-treatment baseline ($MEP_{F,Pre1}$ *mean* = 78 66) were not significantly different from MEPs measured for them during the second pre-treatment baseline ($MEP_{F,Pre2}$ *mean* = 85 54, $p = 0$ 985), and MEPs measured for males during the first pre-treatment baseline ($MEP_{M,Pre1}$ *mean* = 110 29) were not significantly different from MEPs measured for them during the second pre-treatment baseline ($MEP_{M,Pre2}$ *mean* = 105 69, $p = 0$ 991). Additionally, MEPs measured for females during the post treatment baseline ($MEP_{F,Post}$ *mean* = 102 18) were not significantly different from MEPs measured for males during any of the pre-treatment baselines ($MEP_{M,Pre1}$ *mean* = 110 29 $p = 0$ 890, $MEP_{M,Pre2}$ *mean* = 105.69 $p = 0$ 992). On the other hand, MEPs measured for males during the post-treatment baseline ($MEP_{M,Post}$ *mean* = 144 59) were significantly higher than any MEPs measured for either sex during any baseline. Furthermore, MEPs measured for females during the post-treatment baseline were significantly higher than those measured for them during any of the pre-treatment baselines ($MEP_{F,Pre1}$ *mean* = 78 66 $p = 0$ 013, $MEP_{F,Pre2}$ *mean* = 85 54, $p = 0$ 008). Finally, for any of the pre-treatment baselines, MEPs measured for males were significantly higher than those measured for females.

Table 3 3 Results of Tukey s simple effect tests exploring the effects of Gender and Baseline on MEP

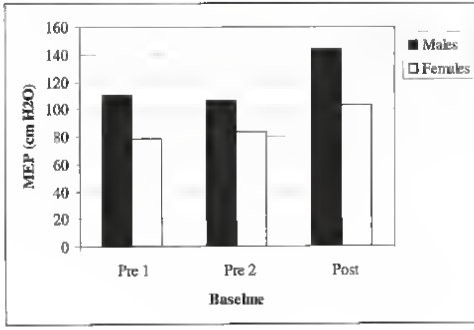
Independent Variable Combinations (I)	(J)	Mean (I)	Mean (J)	Mean Difference (I-J)	Std. Error	P value
1 F, Post	2 F, Pre 1	102.18	78.66	24.67	7 964	0 013*
	3 F, Pre 2		82 54	19 76	7.577	0.002*
	4 M, Post		144 59	-40 5	5 734	< 0.001*
	5 M, Pre 1		110 29	-6 96	5 806	0.890
	6 M, Pre 2		105 69	3.33	5 700	0.992
2 F, Pre 1	3 F, Pre 2	78 66	83 57	-4.91	5.852	0.955
	4 M, Post		144 59	-65 17	7 022	< 0 001*
	5 M, Pre 1		110 29	-31 63	7 752	0.001*
	6 M, Pre 2		105 69	-28 00	7.358	0.001*
3 F, Pre 2	4 M, Post	83 57	144 59	-60.26	6 075	< 0.001*
	5 M, Pre 1		110 29	-26 72	7.150	0.001*
	6 M, Pre 2		105 69	-23.09	6.710	< 0.001*
4 M, Post	5 M, Pre 1	144 59	110 29	33.54	6 063	< 0.001*
	6 M, Pre 2		105 69	37 17	5 132	< 0.001*
5 M, Pre 1	6 M, Pre 2	110 29	105 69	3.63	4 901	0 991

* indicates that the mean difference is significant at $\alpha = 0.05$

F = Females

M = Males

Figure 3.1: The effects of Gender and Baseline on MEPs



Pulmonary Function

A three-way multivariate analysis of variance (MANOVA) was conducted to determine the effects of gender, baseline, and medication status on the three dependent variables of FEV1, FEV1/FVC, and MEF. MANOVA results, presented in Table 3-4, revealed that the three-way interaction between the factors was not significant at $\alpha = 0.05$ (*Wilks* $\Lambda = 0.940$, $F_{6,236} = 1.25$, $p = 0.283$). The two way interaction between factors was then examined and revealed nonsignificance for the interactions between gender and baseline (*Wilks* $\Lambda = 0.970$, $F_{6,236} = 0.60$, $p = 0.729$), or medication status and baseline (*Wilks'* $\Lambda = 0.920$, $F_{6,236} = 1.68$, $p = 0.127$). However, a significant one was found for the interaction between gender and medication status (*Wilks* $\Lambda = 0.911$, $F_{3,118} = 3.85$, $p = 0.011$). Therefore, the main effect of baseline was examined and revealed that baseline significantly affect the combined dependent variable of FEV1, FEV1/FVC, and MEF (*Wilks* $\Lambda = 0.605$, $F_{6,236} = 11.23$, $p < 0.001$). Univariate ANOVAs and Tukey's post hoc tests were conducted as follow up tests. Prior to examining the ANOVA results, the alpha level was adjusted utilizing the Bonferroni adjustment to counteract the potential of an inflated error rate due to the multiple uses of ANOVAs (Mertler & Vannatta, 2001). Consequently, the overall α-level was divided by the number of dependent variables (i.e., 3) to achieve the adjusted α-level. Accordingly, the adjusted α level was determined to be $0.05/3 = 0.0167$. Univariate ANOVA results, presented in Table 3-5, reveal no significant interaction between the factors of gender and medication status on any of the dependent variables of FEV1 ($F_{1,120} = 1.82$, $p = 0.179$), FEV1/FVC ($F_{1,120} = 2.32$, $p = 0.130$), or MEF ($F_{1,120} = 1.40$, $p = 0.239$). ANOVA results also indicate that FEV1 significantly differs for gender [$F_{1,120} = 380.46$, $p < 0.001$) and baseline ($F_{2,120} = 9.24$, p

Table 3-4 MANOVA results of the effects of Gender Baseline and Medication status on pulmonary function.

Effect	Statistic	Value	F value	Hypothesis DF	Error DF	P value
Medication	Wilks Λ	0.953	1.95	3	118	0.126
Baseline	Wilks Λ	0.605	11.23	6	236	< 0.001*
Gender	Wilks Λ	0.433	2.62	3	6	0.146
Medication x Baseline	Wilks Λ	0.920	1.68	6	236	0.127
Gender x Medication	Wilks Λ	0.911	3.85	3	118	0.011*
Gender x Baseline	Wilks Λ	0.970	0.60	6	236	0.729
Gender x Medication x Baseline	Wilks Λ	0.940	1.25	6	236	0.283

* indicates that the mean difference is significant at $\alpha = 0.05$

Table 3-5 Univariate ANOVAs summary table for pulmonary function dependent variables

Source	Dependent Veriable	DF	Type I SS	Mean Square	F value	P value
Model	FEV1/FVC	19	12717 970	669 367	10 34	< 0 001
	FEV1	19	67.992	3 579	49.23	< 0 001
	MEF	19	647 929	34 102	129 80	< 0.001
Medication	FEV1/FVC	1	62 522	62 522	0 97	0 328
	FEV1	1	0 000	0 000	0 75	0 389
	MEF	1	0 002	0 002	0 01	0 936
Baseline	FEV1/FVC	2	503 901	251 951	3 89	0 023
	FEV1	2	0 444	0 222	9 24	0.001*
	MEF	2	22.692	11 346	43.19	< 0.001*
Gender	FEV1/FVC	1	5 442	5 442	0 08	0 772
	FEV1	1	15.025	15.025	380 46	< 0.001*
	MEF	1	159 114	159 114	605 64	< 0 001*
Medication x Baseline	FEV1/FVC	2	170 328	85 164	1 32	0 272
	FEV1	2	0.172	0.086	1 48	0.311
	MEF	2	1 152	0 576	2 19	0 116
Gender x Medication	FEV1/FVC	1	150 446	150 446	2 32	0 130
	FEV1	1	0 151	0 151	1 82	0 179
	MEF	1	0.367	0.367	1 40	0 239
Gender x Baseline	FEV1/FVC	2	311 825	155.913	2 41	0.094
	FEV1	2	0 198	0.099	1 36	0 259
	MEF	2	1 161	0 580	2.21	0 114
Gender x Medicatioe x Baseline	FEV1/FVC	2	41 512	20 756	0 32	0 726
	FEV1	2	0 027	0 013	0 18	0 834
	MEF	2	0 629	0 314	1 20	0 306
Error	FEV1/FVC	120	7769 581	64 747		
	FEV1	120	8 723	0.073		
	MEF	120	31.527	0 263		
Corrected Total	FEV1/FVC	139	20487 550			
	FEV1	139	76 715			
	MEF	139	679 456			

* indicates that the mean difference is significant at α = 0 0167

= 0 001) but not for medication status ($F_{1,120} = 0\ 75$, $p = 0\ 389$). Similarly, MEF significantly differs for gender ($F_{1,120} = 605\ 64$, $p < 0\ 001$) and baseline ($F_{2,120} = 43\ 19$, $p < 0\ 001$), but not for medication status ($F_{1,120} = 0\ 01$, $p = 0\ 936$). However, the FEV1/FVC ratio does not significantly differ for gender ($F_{1,120} = 0\ 08$, $p = 0\ 772$), medication status ($F_{1,120} = 0\ 97$, $p = 0\ 328$) or baseline ($F_{2,120} = 3\ 89$, $p = 0\ 023$). Tukey's post hoc results for gender presented in Table 3 6 indicate that male participants have significantly higher FEV1 ($FEV1_M$ *mean* = 2 88, $p < 0\ 001$) and MEF (MEF_M *mean* = 6 06, $p < 0\ 001$) means than females do ($FEV1_F$ *mean* = 2 01, MEF_F *mean* = 3 85) see Figures 3-2 and 3-3. Post-hoc results for FEV1 and baseline, presented in Table 3-7, indicate no significant difference between FEV1 measurements taken during the two pre-treatment baseline measures ($p = 0\ 862$). These results further indicate a significant difference between FEV1 measured during the post-treatment baseline ($FEV1_{Post}$ *mean* = 2 57) and that measured during any of the pre-treatment baselines ($FEV1_{Pre1}$ *mean* = 2 37, $p = 0\ 005$; $FEV1_{Pre2}$ *mean* = 2 38, $p < 0\ 001$), see Figure 3-4. In contrast, post-hoc results for MEF and baseline, also presented in Table 3-7, indicate significant differences among MEF measurements taken during the three baselines, see Figure 3-5. For the pre-treatment baselines, MEFs measured during the second baseline (MEF_{Pre2} *mean* = 4 914) were significantly higher than those measured during the first baseline (MEF_{Pre1} *mean* = 4 45, $p = 0\ 006$). On the other hand, MEFs measured during the post-treatment baseline (MEF_{Post} *mean* = 5.51) were significantly higher than those measured during the first ($p < 0\ 001$) or the second ($p < 0\ 001$) pre-treatment baselines.

Table 3-6 Post hoc tests for FEV1 and MEF by Gender

Dependent Variable	Independent Variable Combinations (I)	(J)	Mean (I)	Mean (J)	Mean Difference (I-J)	Std. Error	P value
FEV1	F	M	2.008	2.883	-0.875	0.061	< 0.001*
MEF	F	M	3.846	6.064	2.218	0.116	< 0.001*

Table 3-7 Post hoc tests for FEV1 and MEF by Baseline

Dependent Variable	Independent Variable Combinations (I)	(J)	Mean (I)	Mean (J)	Mean Difference (I-J)	Std. Error	P value
FEV1	Post	Pre 1	2.578	2.370	0.208	0.088	0.005*
	Post	Pre 2	2.578	2.382	0.196	0.116	< 0.001*
	Pre 1	Pre 2	2.370	2.382	0.012	0.013	0.862
MEF	Post	Pre 1	5.505	4.448	1.057	0.148	< 0.001*
	Post	Pre 2	5.505	4.914	0.591	0.128	< 0.001*
	Pre 1	Pre 2	4.448	4.914	-0.466	0.148	0.006*

* indicates that the mean difference is significant at $\alpha = 0.0167$

Figure 3 2 Effect of Gender on FEV1

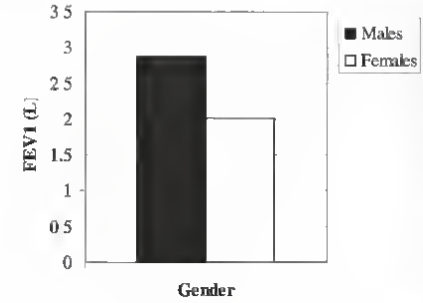


Figure 3 3 Effect of Gender on MEF

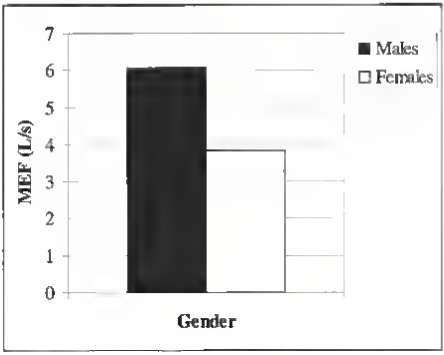


Figure 3-4 Mean FEV1 values at different Baselines.

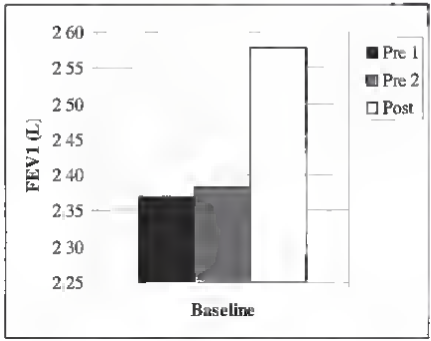
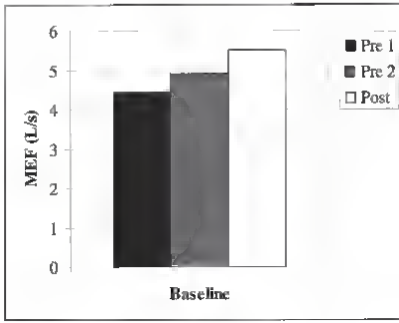


Figure 3-5 Mean MEF values at different Baselines



Cough Function

A MANOVA was conducted to determine the effects of gender, baseline, and medication status on the dependent variables of inspiratory phase duration (IPD), compression phase duration (CPD), peak expiratory flow rate (PEFR), post-peak plateau duration (PPPD), and post-peak plateau amplitude (PPPA). MANOVA results, presented in Table 3-8, revealed that the three-way interaction among the factors was significant at $\alpha = 0.05$ ($Wilks\ \Lambda = 0.807$, $F_{18,232} = 2.63$, $p = 0.005$). Therefore, univariate ANOVAs and Tukey's post-hoc tests were conducted as follow-up tests. Prior to examining the ANOVA results, the alpha level was adjusted utilizing the Bonferroni adjustment described earlier. Consequently, the adjusted α level was determined to be 0.05/5 = 0.010. Univariate ANOVA results, presented in Table 3-9, reveal no significant three-way interactions among the factors of gender, medication status, and baseline on the dependent variable of IPD ($F_{2,120} = 4.37$, $p = 0.015$), nor was there a significant two-way interaction between the factors (medication status x baseline: $F_{2,120} = 0.62$, $p = 0.542$, gender x baseline: $F_{2,120} = 0.86$, $p = 0.425$, gender x medication status: $F_{1,120} = 0.33$, $p = 0.566$). Main effects were then examined and revealed that inspiratory phase duration differs for baseline ($F_{2,120} = 18.96$, $p < 0.001$), medication status ($F_{1,120} = 10.79$, $p = 0.001$), and gender ($F_{1,120} = 32.04$, $p < 0.001$). Tukey's post hoc results, presented in Table 3-10 and depicted in Figure 3-6, for inspiratory phase duration and baseline indicate no significant differences between the two pre-treatment baselines ($IPD_{Pre\,1}$ $mean = 1.53$, $IPD_{Pre\,2}$ $mean = 1.36$, $p = 0.026$) in IPD. Inspiratory phase durations measured during the post-treatment baseline (IPD_{Post} $mean = 1.19$), however, were significantly different than those measured during the first ($p < 0.001$) or second ($p =$

Table 3.8: MANOVA results of the effects of Gender, Baseline and Medication Status on cough measures

Effect	Statistic	Value	F value	Hypothesis DF	Error DF	P value
Medication	Wilks Λ	0.835	4.59	5	116	0.001
Baseline	Wilks Λ	0.557	7.90	10	232	< 0.001
Gender	Wilks Λ	0.567	0.61	5	4	0.701
Medication x Baseline	Wilks Λ	0.833	2.22	10	232	0.017
Medication x Gender	Wilks Λ	0.911	2.58	5	116	0.052
Baseline x Gender	Wilks Λ	0.695	4.62	10	232	< 0.001
Gender x Medication x Baseline	Wilks Λ	0.807	2.63	10	232	0.005*

* indicates that the mean difference is significant at $\alpha = 0.05$

Table 3-9 Univariate ANDVAs summary table for cough dependent variables

Source	Dependent Variable	DF	Type I SS	Mean Square	F value	P value
Model	IPD	19	38.257	2.014	39.99	< 0.001
	CPD	19	5.843	0.308	46.59	< 0.001
	PEFR	19	610.888	32.152	46.47	< 0.001
	PPPD	19	0.519	0.027	16.25	< 0.001
	PPPA	19	364.291	19.173	30.67	< 0.001
Medication	IPD	1	0.543	0.543	10.79	0.001*
	CPD	1	0.020	0.020	3.05	0.083
	PEFR	1	10.673	10.673	15.43	< 0.001*
	PPPD	1	0.004	0.004	2.37	0.126
	PPPA	1	5.158	5.158	8.25	0.005
Baseline	IPD	2	1.910	0.955	18.96	< 0.001*
	CPD	2	0.069	0.034	5.21	0.007
	PEFR	2	14.942	7.471	10.80	< 0.001
	PPPD	2	0.011	0.005	3.23	0.043
	PPPA	2	20.342	10.171	16.27	< 0.001
Gender	IPD	1	1.613	1.613	32.04	< 0.001*
	CPD	1	0.000	0.000	0.00	0.993
	PEFR	1	237.996	237.996	344.00	< 0.001
	PPPD	1	0.016	0.016	16.25	0.003*
	PPPA	1	45.584	45.584	72.92	< 0.001
Medication x Baseline	IPD	2	0.062	0.031	0.62	0.542
	CPD	2	0.012	0.006	0.90	0.411
	PEFR	2	5.314	2.657	3.84	0.024
	PPPD	2	0.013	0.006	3.62	0.030
	PPPA	2	0.797	0.399	0.64	0.530
Gender x Medication	IPD	1	0.017	0.017	0.33	0.566
	CPD	1	0.082	0.082	12.43	0.001*
	PEFR	1	0.122	0.122	0.18	0.676
	PPPD	1	0.003	0.003	1.97	0.163
	PPPA	1	0.009	0.009	0.01	0.904
Gender x Baseline	IPD	2	0.087	0.043	0.86	0.425
	CPD	2	0.107	0.053	8.10	0.001*
	PEFR	2	27.429	13.714	19.82	< 0.001*
	PPPD	2	0.008	0.004	2.52	0.085
	PPPA	2	4.088	2.044	3.27	0.041
Gender x Medication x Baseline	IPD	2	0.440	0.220	4.37	0.015
	CPD	2	0.013	0.006	0.99	0.376
	PEFR	2	2.481	1.240	1.79	1.171
	PPPD	2	0.013	0.006	3.83	0.024
	PPPA	2	9.713	4.857	7.77	0.001*

Error	IPD	120	6.042	0.050		
	CPD	120	0.792	0.007		
	PEFR	120	83.021	0.692		
	PPPD	120	0.202	0.002		
	PPPA	120	75.015	0.625		
Corrected Total	IPD	139	44.299			
	CPD	139	6.635			
	PEFR	139	693.908			
	PPPD	139	0.721			
	PPPA	139	439.306			

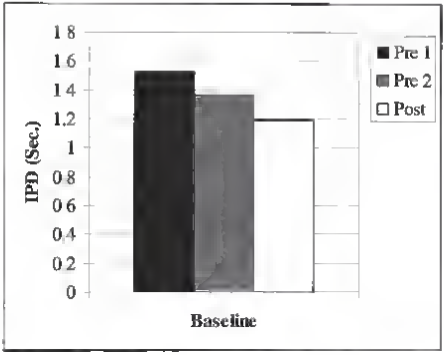
* indicates that the mean difference is significant at $\alpha = 0.010$

Table 3.10: Post hoc tests for IPD by Baseline

Dependent Variable	Independent Variable Combinations (I)	(J)	Mean (I)	Mean (J)	Mean Difference (I-J)	Std. Error	P value
IPD	Post	Pre 1	1.193	1.531	-0.338	0.065	< 0.001*
	Post	Pre 2	1.193	1.361	-0.168	0.056	0.009*
	Pre 1	Pre 2	1.531	1.361	0.170	6.538	0.026

* indicates that the mean difference is significant at $\alpha = 0.010$

Figure 3-6 IPD mean values at different Baselines



0 009) pre treatment baselines On the other hand, post hoc results for IPD and medication status presented in Table 3 11 and depicted in Figure 3 7, indicate that IPDs measured during the ON medication status (IPD_{ON} *mean* = 1 25) were significantly higher than those measured during the OFF medication status (IPD_{OFF} *mean* = 1 15, $p <$ 0 001) Finally, post hoc results for IPD and gender, presented in Table 3-11 and depicted in Figure 3 8, indicate that male participants (IPD_M *mean* = 1 47) had a significantly longer inspiratory phase than female participants did (IPD_F *mean* = 1.25, p < 0 001)

The results of the univariate ANOVA for CPD, presented in Table 3 9, reveal no significant three-way interaction among the factors ($F_{2,120} = 0\ 99$, $p = 0.376$) Examining the two-way interactions indicates a significant interaction between gender and baseline ($F_{2\ 120} = 8\ 10$, $p = 0\ 001$) and gender and medication status ($F_{1\ 120} = 12.43$, $p = 0\ 001$) but not between the factors of medication status and baseline ($F_{2\ 120} = 0\ 90$, $p = 0\ 411$) Simple effect tests were conducted to further explore the effect of gender and baseline on CPD Results, presented in Table 3 12 and depicted in Figure 3-9, revealed that the CPDs measured for female participants during the first pre-treatment baseline ($CPD_{F\ Pre1}$ *mean* = 0.35) were significantly longer than those measured for females during other baselines ($CPD_{F\ Pre2}$ *mean* = 0.21 $p = 0\ 002$ $CPD_{F\ Post}$ *mean* = 0.22 $p = 0.005$) and were significantly longer than those measured for males during the first pre-treatment ($CPD_{M,\ Pre1}$ *mean* = 0.21, $p = 0\ 003$) or the post-treatment baselines ($CPD_{M\ Post}$ *mean* = 0 20, $p < 0\ 001$) No significant differences were found between CPDs measured for males during the two pre-treatment baselines ($CPD_{M,\ Pre1}$ *mean* = 0 21, $CPD_{M,\ Pre2}$ *mean* = 0 24, $p = 0\ 904$) or those measured for males during the post treatment baseline and

Table 3-11 Post hoc tests for IPD by Medication Status and by Gender

Dependent Variable	Independent Variable Combinations (I)	(J)	Mean (I)	Mean (J)	Mean Difference (I-J)	Std Error	P value
IPD	OFF	ON	1 147	1 254	-0 107	0 025	< 0 001*
	M	F	1 472	1 250	0 222	0 051	< 0 001*

* indicates that the mean difference is significant at $\alpha = 0.010$

Figure 3-7 Effects of Medication Status on IPD

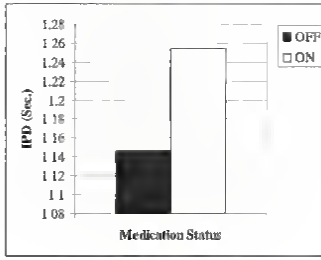


Figure 3 8 Effects of Gender on IPD

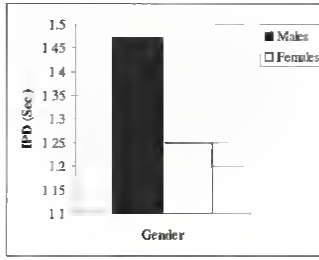
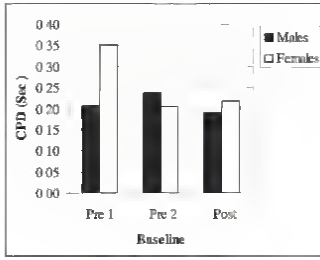


Table 3-12. Results of Tukey s simple effect tests for the effects of Gender and Baseline on CFD

Independent Variable Combinations (I)	(J)	Mean (I)	Mean (J)	Mean Difference (I-J)	Std. Error	P value
1 F, Post	2 F, Pre 1	0 218	0 350	0 132	0.036	0.005*
	3 F, Pre 2		0 205	-0 013	0 033	0 998
	4 M, Post		0 191	-0 027	0 029	0 938
	5 M, Pre 1		0 208	-0 01	0 032	1 000
	6 M, Pre 2		0 238	0 02	0 028	0 979
2 F, Pre 1	3 F, Pre 2	0 350	0 205	-0 145	0 036	0 0016*
	4 M, Post		0 191	-0 159	0 034	< 0 001*
	5 M, Pre 1		0 208	-0 142	0 037	0 003*
	6 M, Pre 2		0 238	-0 112	0 034	0 016
3 F, Pre 2	4 M, Post	0.205	0 191	-0 014	0 028	0 996
	5 M, Pre 1		0 208	0 003	0 039	1 000
	6 M, Pre 2		0 238	0 033	0 028	0 855
4 M, Post	5 M, Pre 1	0.191	0 208	0 017	0 030	0 993
	6 M, Pre 2		0 238	0 047	0 025	0 439
5 M, Pre 1	6 M, Pre 2	0 208	0 238	0 03	0 029	0 904

* indicates that the mean difference is significant at $\alpha = 0.01$

Figure 3 9 Effects of Gender and Baseline on CPD



those measured for them during the first ($p = 0.993$) or second ($p = 0.439$) pre-treatment baselines. Simple effect tests were also conducted to further explore the effects of gender and medication status on compression phase duration. Results, presented in Table 3.13 and depicted in Figure 3-10, revealed that CPD measured for males during the OFF medication status ($CPD_{M, OFF}$ *mean* = 0.25) were significantly longer than those measured for them ON medications ($CPD_{M, ON}$ *mean* = 0.17, $p = 0.008$).

Examining the univariate ANOVA results for PEFR, presented in Table 3.9, revealed no significant three-way interaction among the factors ($F_{2,120} = 1.79$, $p = 0.171$) nor was there a significant difference in the two-way interactions between medication status and baseline ($F_{2,120} = 3.84$, $p = 0.024$), or gender and medication status ($F_{1,120} = 0.18$, $p = 0.676$). There was, however, a significant two-way interaction between the factors of gender and baseline ($F_{2,120} = 19.82$, $p < 0.001$). Further, the main effect of medication status was also significant ($F_{1,120} = 15.43$, $p < 0.001$). Therefore, a Tukey's post hoc test was conducted to further explore the effects of medication status on PEFR. Results, presented in Table 3.14 and depicted in Figure 3.11, indicate that PEFRs measured for participants during the OFF medication status ($PEFR_{OFF}$ *mean* = 8.29) were significantly higher than those measured for them ON medications ($PEFR_{ON}$ *mean* = 7.75, $p = 0.001$). In addition, simple effect tests were carried out to further explore the effects of gender and baseline on PEFR. Results, presented in Table 3.15 and depicted in Figure 3-12, indicate that PEFRs measured for males in any baseline were significantly higher than those measured for females during any baseline. In addition, PEFRs measured for males during the post treatment baseline ($PEFR_{M, Post}$ *mean* = 10.04) were

Table 3 13 Results of Tukey's simple effect tests for the effects of Gender and Medication Status on CPD

Independent Variable Combinations (I)	(J)	Mean (I)	Mean (J)	Mean Difference (I-J)	Std. Error	P value
1 F, OFF	2 F, ON	0 246	0 270	0 024	0 028	0 844
	3 M, OFF		0 250	0 004	0 004	0 997
	4 M, ON		0 174	-0 072	2 769	0 026
2 F, ON	3 M, OFF	0 270	0 250	-0 02	0 022	0 892
	4 M, ON		0 174	-0 096	0 800	0 012
3 M, OFF	4 M, ON	0 250	0 174	-0 076	9 5	0 004*

* indicates that the mean difference is significant at $\alpha = 0.01$

Figure 3.10: Effects of Gender and Medication Status on CPD

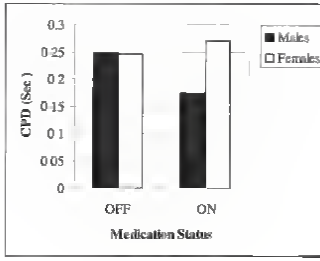


Table 3-14 Post hoc tests for PEFR by Medication Status

Dependent Variable	Independent Variable Combinations (I)	(J)	Mean (I)	Mean (J)	Mean Difference (I-J)	Std. Error	P value
PEFR	OFF	ON	8 289	7 745	0 544	0 251	0 001*

* indicates that the mean difference is significant at $\alpha = 0.010$

Figure 3-11 Effect of Medication Status on PEFR

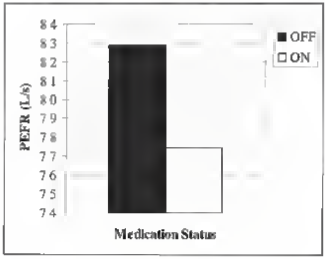
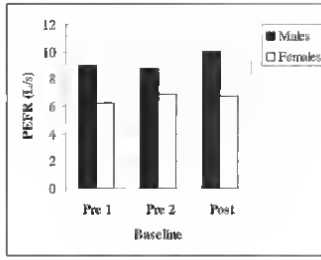


Table 3.15: Results of Tukey s simple effect tests for the effects of Gender and Baseline on PEFR.

Independent Variable Combinations (I)	(J)	Mean (I)	Mean (J)	Mean Difference (I-J)	Std. Error	P value
1 F, Post	2 F, Pre 1	6.760	6.230	0.530	0.372	0.712
	3 F, Pre 2		6.900	-0.140	0.322	0.998
	4 M, Post		10.043	-3.283	0.294	< 0.001*
	5 M, Pre 1		9.062	-2.302	0.331	< 0.001*
	6 M, Pre 2		8.764	2.004	0.294	< 0.001*
2 F, Pre 1	3 F, Pre 2	6.230	6.900	-0.670	0.372	0.469
	4 M, Post		10.043	-3.813	0.348	< 0.001*
	5 M, Pre 1		9.062	-2.832	0.380	< 0.001*
	6 M, Pre 2		8.764	-2.534	0.348	< 0.001*
3 F, Pre 2	4 M, Post	6.900	10.043	-3.143	0.294	< 0.001*
	5 M, Pre 1		9.062	-2.162	0.331	< 0.001*
	6 M, Pre 2		8.764	-1.864	0.294	< 0.001*
4 M, Post	5 M, Pre 1	10.043	9.062	0.981	0.304	0.020
	6 M, Pre 2		8.764	1.279	0.263	< 0.001*
5 M, Pre 1	6 M, Pre 2	9.062	8.764	0.298	0.303	0.923

* indicates that the mean difference is significant at $\alpha = 0.01$

Figure 3.12. Effects of Baseline and Gender on PEFR



significantly higher than those measured for them during the second pre-treatment baseline ($PEFR_{M,\ Pre2}$ *mean* = 8 76, $p < 0.001$) No significant differences were found, however, between PEFRs measured for males during the post-treatment baseline and those measured for them during the first pre treatment baseline ($PEFR_{M\ Pre1}$ *mean* = 9 06, $p = 0.020$) Further no significant differences were found between PEFRs measured for males during the first and second pretreatment baselines ($p = 0.923$) nor were there any differences among PEFRs measured for females during any of the baselines.

The effects of gender medication status, and baseline on PPPD were analyzed using a univariate ANOVA Results presented in Table 3-9 indicated no significant two- or three-way interactions among the factors Results, however, revealed a significant main effect for gender ($F_{1,120} = 16.25$, $p = 0.003$) but not for medication status ($F_{1,120} = 2.37$, $p = 0.126$), or baseline ($F_{2,120} = 3.23$, $p = 0.043$) The mean PPPD for male participants ($PPPD_{M}$ *mean* = 0 13) was significantly longer than that measured for females ($PPPD_{F}$ *mean* = 0 02, $p < 0.001$), see Table 3-16 and Figure 3 13

Finally, a univariate ANOVA was conducted to evaluate the effects of gender, medication status, and baseline on PPPA Results, presented in Table 3 9 revealed a significant three way interaction among the factors ($F_{2,120} = 7.77$, $p = 0.001$). Therefore, simple effect tests were carried out. Results, presented in Table 3 17 and depicted in Figure 3 14, indicate that PPPAs measured for male participants during the post-treatment baseline OFF medications ($PPPA_{M\ OFF\ Post}$ *mean* = 6 33) were significantly higher than those measured for females during the pre-treatment baselines in any medication status those measured for females in the OFF medications during any of the

Table 3-16 Post hoc tests for PPPD by Gender

Dependent Variable	Independent Variable Combinations (I)	(J)	Mean (I)	Mean (J)	Mean Difference (I-J)	Std Error	P value
PPPD	M	F	0 130	0 019	0 111	0 050	< 0 001*

* indicates that the mean difference is significant at a = 0 010

Figure 3-13 Effects of Gender on PPPD

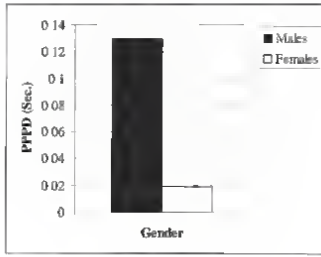


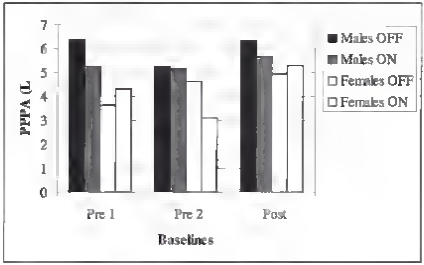
Table 3-17 Results of Tukey s simple effect tests for the effects of Gender Medication Status and Baseline on PPPA.

Independent Variable Combinations (I)	(J)	Mean (I)	Mean (J)	Mean Difference (I-J)	Std Error	P value
1 F_OFF_Post	2 F_OFF_Pre 1	4 908	3 625	1 283	0 433	0 133
	3 F_OFF_Pre 2		4 643	0 265	0,250	0,996
	4 F_ON_Post		5 290	-0 382	0 433	0,999
	5 F_ON_Pre 1		4 283	0,625	0,433	0,952
	6 F_ON_Pre 2		3 108	1 800	0 433	0.003
	7 M_OFF_Post		6 327	-1 419	0 228	< 0.001*
	8 M_OFF_Pre 1		6 365	-1 457	0 368	0,007
	9 M_OFF_Pre 2		5 257	-0 349	0 228	0 929
	10 M_ON_Post		5 675	-0 767	0 368	0,634
	11 M_ON_Pre 1		5 247	-0 339	0 368	0,999
	12 M_ON_Pre 2		5 158	-0 250	0,367	1.000
2 F_OFF_Pre 1	3 F_OFF_Pre 2	3 625	4 643	-1 0180	0 433	0,448
	4 F_ON_Post		5 290	-1 665	0 560	0 128
	5 F_ON_Pre 1		4 283	-0 658	0 560	0,990
	6 F_ON_Pre 2		3 108	0 517	0 558	0,999
	7 M_OFF_Post		6 327	-2 702	0 421	< 0.001*
	8 M_OFF_Pre 1		6 365	-2 74	0 510	< 0.001*
	9 M_OFF_Pre 2		5 257	-1 632	0 421	0 009*
	10 M_ON_Post		5 675	-2 050	0 510	0,006*
	11 M_ON_Pre 1		5 247	-1 622	0 511	0 077
	12 M_ON_Pre 2		5 158	-1 533	0 510	0 120
3 F_OFF_Pre 2	4 F_ON_Post	4 643	5 290	-0 647	0 433	0,939
	5 F_ON_Pre 1		4 283	0 360	0 433	1.000
	6 F_ON_Pre 2		3 108	1 535	0 433	0,027
	7 M_OFF_Post		6 327	1 684	0 228	< 0.001*
	8 M_OFF_Pre 1		6 365	-1 722	0 368	0.001*
	9 M_OFF_Pre 2		5 257	-0 614	0 228	0,244
	10 M_ON_Post		5 675	1 032	0 368	0 ,191
	11 M_ON_Pre 1		5 247	-0 604	0 368	0 ,990
	12 M_ON_Pre 2		5 158	-0 515	0 368	0,961
4 F_ON_Post	5 F_ON_Pre 1	5 290	4 283	1 007	0 559	0 814
	6 F_ON_Pre 2		3 108	2 181	0 559	0 008*
	7 M_OFF_Post		6 327	-1 037	0 421	0 373
	8 M_OFF_Pre 1		6 365	1 075	0 510	0 619
	9 M_OFF_Pre 2		5 257	0 033	-0 418	1 000
	10 M_ON_Post		5 675	-0 385	0 511	1 000
	11 M_ON_Pre 1		5 247	0 043	0 506	1 000

	12 M_ON_Pre 2		5 158	0 132	0 512	1 000
5 F_ON_Pre 1	6 F_ON_Pre 2	4 283	3 108	1 175	0 559	0 623
	7 M_OFF_Post		6 327	-2 044	0 421	< 0 001*
	8 M_OFF_Pre 1		6 365	2 082	0 510	0 005*
	9 M_OFF_Pre 2		5 257	-0 974	0 421	0 472
	10 M_ON_Post		5 675	-1 392	0 510	0 226
	11 M_ON_Pre 1		5 247	0 964	0 510	0 764
	12 M_ON_Pre 2		5 158	0 875	0 510	0 857
6 F_ON_Pre 2	7 M_OFF_Post	3 108	6 327	3 219	0 421	< 0 001*
	8 M_OFF_Pre 1		6 365	3 257	0 510	< 0 001*
	9 M_OFF_Pre 2		5 257	2 149	0 421	< 0 001*
	10 M_ON_Post		5 675	2 567	0 510	< 0 001*
	11 M_ON_Pre 1		5 247	2 139	0 510	0 003*
	12 M_ON_Pre 2		5 158	2 050	0 510	0 006*
7 M_OFF_Post	8 M_OFF_Pre 1	6 327	6 365	0 038	0 352	1 000
	9 M_OFF_Pre 2		5 257	1 070	0 204	< 0 001*
	10 M_ON_Post		5 675	0 652	0 354	0 791
	11 M_ON_Pre 1		5 247	1 080	0 354	0 106
	12 M_ON_Pre 2		5 158	1 169	0 354	0 054
8 M_OFF_Pre 1	9 M_OFF_Pre 2	6 365	5 257	1 108	0 353	0 086
	10 M_ON_Post		5 675	0 690	0 456	0 935
	11 M_ON_Pre 1		5 247	1 118	0 456	0 382
	12 M_ON_Pre 2		5 158	1 207	0 457	0 268
9 M_OFF_Pre 2	10 M_ON_Post	5 257	5 675	-0 418	0 353	0 989
	11 M_ON_Pre 1		5 247	0 010	0 357	1 000
	12 M_ON_Pre 2		5 158	0 099	0 356	1 000
10 M_ON_Post	11 M_ON_Pre 1	5 675	5 247	0 428	0 456	1 000
	12 M_ON_Pre 2		5 158	0 517	0 457	0 993
11 M_ON_Pre 1	12 M_ON_Pre 2	5 247	5 158	0 089	0 459	1 000

* indicates that the mean difference is significant at $\alpha = 0.010$

Figure 3 14 Effects of Gender_Baseline, and Medication Status on PPPA



baselines and those measured for males OFF medications during the second pre-treatment baseline ($PPPA_{M,\ OFF\ Pre2}$ $mean = 5.26$ $SD = ,$ $p < 0.001$) Results also indicate that PPPAs measured for males during the post treatment baseline OFF medications were not significantly different from those measured for males ON medications during any of the baselines nor were they significantly different from those measured for males OFF medications during the first pre-treatment baseline ($PPPA_{M,\ OFF\ Pre1}$ $mean = 6.37$ $p = 1.00$) or those measured for females ON medications during the post-treatment baseline ($PPPA_{F\ ON\ Post}$ $mean = 5.29$, $p < 0.001$) Results also indicate that PPPAs measured for males OFF medications during the first pre-treatmeot baseline ($PPPA_{M,\ OFF\ Pre1}$ $mean = 6.37$) were significantly higher than those measured for females OFF medications during any baseline and those measured for females ON medications during any of the pre-treatment baselines However PPPAs measured for males OFF medications during the first pre treatment baseline were not significantly different from measurements made for male participants at any medication status during any baseline In contrast PPPAs measured for male participants OFF medications during the second pre-treatment baseline ($PPPA_{M\ OFF\ Pre2}$ $mean = 5.26$) were significantly higher than only those measured for female participants ON medications during the second pre-treatment baseline ($PPPA_{F\ ON\ Pre2}$ $mean = 3.11$, $p < 0.001$) and female participants OFF medications during the first pre treatment baseline ($PPPA_{F\ OFF\ Pre1}$ $mean = 3.63$ $p = 0.009$) In addition results also showed that PPPAs measured for males ON medications during the post treatment baseline ($PPPA_{M\ ON\ Post}$ $mean = 5.65$) were significantly higher than those measured for females OFF medications during the first pre-treatment baseline ($PPPA_{F\ OFF\ Pre1}$ $mean = 3.63$, $p = 0.006$) and females ON medications during the second

pre-treatment baseline ($PPPA_{F\ ON\ Pre2}$ $mean = 3.11$, $p < 0.001$). Furthermore, PPPAs measured for females ON medications during the second pre-treatment baseline were significantly lower than those measured for males ON medications during any of the pre-treatment baselines and those measured for females during the post-treatment baseline in any medication status.

Swallowing Quality of Life

A repeated measures ANOVA was conducted to investigate total SWAL-QOL differences in gender and baseline among participants. ANOVA results, presented in Table 3-18, showed no significant interaction between the factors at $\alpha = 0.05$ ($F_{1,60} = 0.13$, $p = 0.722$). A significant main effect was found, however, for gender ($F_{1,60} = 7.43$, $p = 0.008$), but not baseline ($F_{1,60} = 0.19$, $p = 0.663$). The mean total SWAL-QOL score for females ($mean = 188.50$) was significantly higher than that for males ($mean = 183.00$, $p = 0.008$), see Table 3-19 and Figure 3-15.

The Motor Section of the Unified Parkinson's Disease Rating Scale (UPDRS-M)

A repeated measures ANOVA was conducted to investigate total UPDRS score differences in gender, medication status, and baseline among participants. ANOVA results, presented in Table 3-20, showed that the three-way interaction among the factors was not significant at $\alpha = 0.05$ ($F_{2,120} = 0.92$, $p = 0.403$). In addition, the two-way interaction between gender and medication status was not significant at $\alpha = 0.05$ ($F_{1,120} = 1.46$, $p = 0.230$), nor was it significant between the factors of medication status and baseline ($F_{2,120} = 0.15$, $p = 0.862$). However, the two-way interaction between gender and baseline was significant ($F_{2,120} = 3.76$, $p = 0.026$). Further, a significant main effect for medication ($F_{1,120} = 14.33$, $p = 0.001$) was found. Consequently, a Tukey's post-hoc

Table 3-18 Results of the repeated measures ANOVA for SWAL-QOL total score.

Source	DF	Type I SS	Mean Square	F value	P value
Model	11	83312.800	7573.891	96.90	<0.001
Baseline	1	15.000	15.000	0.19	0.663
Gender	1	580.800	580.000	7.43	0.008*
Baseline x Gender	1	10.000	10.000	0.13	0.722
Error	68	5315.000	78.162		
Corrected Total	79	88627.800			

* indicates that the mean difference is significant at α = 0.05

Table 3-19 Post hoc tests for SWAL-QOL total by Gender

Dependent Variable	Independent Variable Combinations (I)	(J)	Mean (I)	Mean (J)	Mean Difference (I-J)	Std. Error	P value
SWAL-QOL Total	M	F	188.50	183.00	5.50	0.040	0.008*

* indicates that the mean difference is significant at α = 0.05

Figure 3-15 Effects of Gender on SWAL-QOL total score

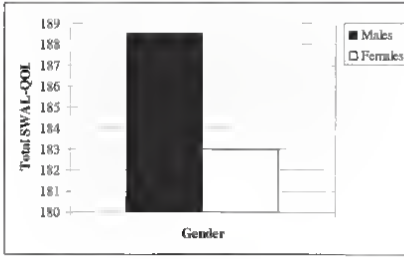


Table 3.20 Results of the repeated measures ANOVA for UPDRS-M total

Source	DF	Type I SS	Mean Square	F value	P value
Model	19	8624.629	433.928	19.02	< 0.001
Medication	1	341.458	341.458	14.31	< 0.001*
Baseline	2	22.080	11.040	0.46	0.631
Gender	1	271.186	281.186	11.78	< 0.001
Medication x Baseline	2	7.085	3.543	0.15	0.862
Gender x Medication	1	34.788	34.788	1.46	0.230
Gender x Baseline	2	179.499	89.750	3.76	0.026*
Gender x Medication x Baseline	2	43.747	21.873	0.92	0.403
Error	120	2863.914	23.866		
Corrected Total	139	11488.543			

* indicates that the mean difference is significant at $\alpha = 0.05$

test was conducted to determine the effects of medications on the total scores of the UPDRS-M. Results, presented in Table 3-21 and depicted in Figure 3-16, reveal that total scores of the UPDRS-M assigned to participants during the OFF medication status (*mean* = 37.30) were significantly higher than those assigned to them during the ON medication status (*mean* = 33.47, $p = 0.001$). Further, Tukey's simple effect tests were carried out to explore the significant interaction between gender and baseline. Results of these tests, presented in Table 3-22, revealed that the only significant difference between the two genders among the three baselines was that between the total UPDRS-M scores assigned to females and males during the post-treatment baseline. Indeed, the mean total UPDRS-M score assigned to males during the post-treatment baseline ($UPDRS\text{-}M_{M,\,Post}$ *mean* = 36.75) was significantly higher than that assigned to females ($UPDRS\text{-}M_{F,\,Post}$ *mean* = 32.88, $p = .011$) during that baseline.

3oz Swallow

A two-way MANOVA was conducted to determine the effects of gender and baseline on the three dependent variables of total duration of 3oz swallow, number of swallows, and PA score. MANOVA results, presented in Table 3-23, indicate nonsignificance for the interactions between the factors (*Wilks* $\Lambda = 0.491$, $F_{2,6} = 2.07$, $p = 0.205$). The main effects were then examined and revealed that gender (*Wilks* $\Lambda = 0.034$, $F_{3,6} = 56.53$, $p < 0.001$), but not baseline (*Wilks* $\Lambda = 0.487$, $F_{3,6} = 2.10$, $p = 0.201$), significantly affect the combined dependent variable of total 3oz swallow duration, number of swallows, and PA score. As follow up tests, three univariate ANOVAs were conducted to evaluate the effects of gender on the dependent variables of total 3oz swallow duration, number of swallows, and PA score. Prior to examining the ANOVA

Table 3-21 Post hoc tests for UPDRS-M total by Medication Status

Dependent Variable	Independent Variable Combinations (I)	(J)	Mean (I)	Mean (J)	Mean Difference (I-J)	Std. Error	P value
UPDRS-M Total	OFF	ON	37 289	33 472	3 817	1 103	0 001*

* indicates that the mean difference is significant at $\alpha = 0\ 05$

Figure 3.16 Effects of Medication Status on total UPDR M scores.

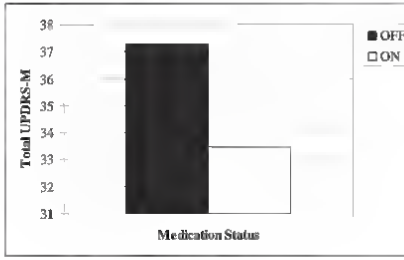


Table 3-22. Results of Tukey s simple effect tests for the effects of Gender and Baseline on UPDRS-M total

Independent Variable Combinations (I)	(J)	Mean (I)	Mean (J)	Mean Difference (I-J)	Std. Error	P value
1 F, Post	2 F, Pre 1	32.875	37.250	-4.375	2.184	0.168
	3 F, Pre 2		33.625	-0.750	1.894	0.796
	4 M, Post		36.750	-3.875	1.727	0.011*
	5 M, Pre 1		35.750	-2.875	1.944	0.404
	6 M, Pre 2		36.033	-3.158	1.727	0.326
2 F, Pre 1	3 F, Pre 2	37.250	33.625	3.625	2.185	0.720
	4 M, Post		36.750	0.500	2.041	1.000
	5 M, Pre 1		35.750	1.500	2.229	0.985
	6 M, Pre 2		36.033	1.217	2.045	0.964
3 F, Pre 2	4 M, Post	33.625	36.750	-3.125	1.727	0.497
	5 M, Pre 1		35.750	-2.125	1.944	0.968
	6 M, Pre 2		36.033	-2.408	1.727	0.943
4 M, Post	5 M, Pre 1	36.750	35.750	1.000	1.783	0.961
	6 M, Pre 2		36.033	0.717	1.545	0.863
5 M, Pre 1	6 M, Pre 2	35.750	36.033	-0.283	1.780	1.000

* indicates that the mean difference is significant at α = 0.05

Figure 3-17 Effects Gender and Baseline on the total UPDRS M scores

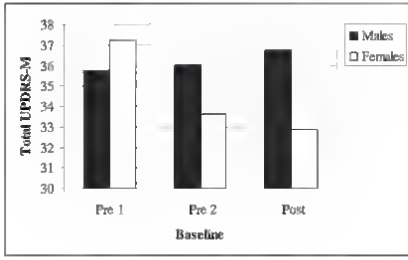


Table 3-23: MANOVA results of the effects of Gender and Baseline on 3oz swallow measures.

Effect	Statistic	Value	F value	Hypothesis DF	Error DF	P value
Baseline	Wilks Λ	0.487	2.10	3	6	0.201
Gender	Wilks Λ	0.034	56.53	3	6	< 0.001*
Baseline x Gender	Wilks Λ	0.491	2.07	3	6	0.205

* indicates that the mean difference is significant at $\alpha = 0.05$

results, the alpha level was adjusted utilizing the Bonferroni adjustment described earlier Consequently the adjusted α-level was determined to be 0 05/3 = 0 0167 Univariate ANOVA results presented in Table 3 24 indicate that gender significantly differs for total swallow duration ($F_{1,9}$ = 52 98 p < 0 001) and number of swallows ($F_{1,9}$ = 14 01, p = 0 011) but not for P-A score ($F_{1,9}$ = 2 21 p = 0 175) Females required a significantly longer time to clear a 3-oz thin liquid (*mean* = 27.58) than males did (*mean* = 12 29) In addition, females required significantly more swallows to clear a 3oz of thin liquid (*mean* = 9 25) than males did (*mean* = 6 33) see Table 3 25 and Figures 3 18 and 3-19

5, and 10cc Swallows

A multivariate analysis of variance (MANOVA) was conducted to determine the effects of gender baseline consistency and bolus size on the dependent variables of pharyngeal response time (PRT) hyoid elevation duration (HED), hyoid anterior motion response time (HAMRT), hyoid anterior motion duration (HAMD), total hyoid movement duration (THMD) closed velopharyngeal port duration (CVPD) P-A score, hyoid elevation displacement ratio (HEDR) and hyoid anterior motion displacement ratio (HAMDR) MANOVA results presented in Table 3 26 revealed that the four-way interaction among the factors was not significant at α = 0 05 (*Wilks' Λ* = 0 824 $F_{9,48}$ = 1 14 p = 0 355) Three way interactions among the factors were also not significant at α = 0 05 (bolus size x baseline x consistency *Wilks' Λ* = 0 747 $F_{9,48}$ = 1.81 p = 0 091 bolus size x consistency x gender *Wilks' Λ* = 0 837, $F_{9,48}$ = 1 04, p = 0 426 bolus size x gender x baseline *Wilks' Λ* = 0 902 $F_{9,48}$ = 0 58 p = 0 806, consistency x gender x baseline *Wilks' Λ* = 0 833 $F_{3,48}$ = 1 07 p = 0 402) The two way interactions between

Table 3-24 Univariate ANOVAs summary table for 3oz swallow dependent variables

Source	Dependent Variable	DF	Type I SS	Mean Square	F value	P value
Model	Duration	11	5949 823	540 893	25 54	< 0 001
	Swallows no	11	205 333	18 667	5 03	0 015
	P A score	11	4 794	0 436	1 43	0 314
Baseline	Duration	1	45 123	45 123	2 13	0 183
	Swallows no	1	1 800	1 800	0 49	0 506
	P-A score	1	1 536	1 536	5 03	0 055
Gender	Duration	1	1122 023	1122 023	52 98	< 0 001*
	Swallows no	1	40 833	40 833	11 01	0 011*
	P A score	1	0 677	0 677	2 21	0 175
Baseline x Gender	Duration	1	101 850	101 850	4 81	0 060
	Swallows no	1	0 533	0 533	0 14	0 714
	P A score	1	0 040	0 040	0 13	0 726
Error	Duration	8	169 416	21 177		
	Swallows no	8	29 667	3 708		
	P A score	8	2 444	0 306		
Corrected Total	Duration	19	6119 238			
	Swallows no	19	235 000			
	P A score	19	7 239			

* indicates that the mean difference is significant at $\alpha = 0.0167$

Table 3-25 Post hoc tests for the effects of Gender on total swallow duration, number of swallows and P-A score during 3oz swallowing

Dependent Variable	Independent Variable Combinations (I)	(J)	Mean (I)	Mean (J)	Mean Difference (I-J)	P value
Duration	M	F	12.292	27.581	-15.289	< 0.001*
Swallows no	M	F	6.333	9.250	-2.917	0.001*
P-A score	M	F	1.806	1.430	0.376	0.152

* indicates that the mean difference is significant at $\alpha = 0.0167$

Figure 3.18: Effect of Gender on total 3oz swallow duration

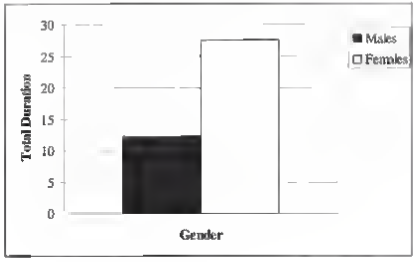


Figure 3-19 Effect of Gender on the number of swallows required to clear a 3oz thin liquid

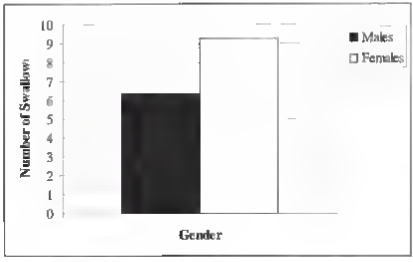


Table 3 26 MANOVA results of the effects of Gender Baseline, Bolus Size and Consistency on 5 and 10cc swallow measures

Effect	Statistic	Value	F value	Hypothesis DF	Error DF	P value
Gender	Wilks Λ	0.350	9.90	9	48	< 0.001*
Bolus Size	Wilks Λ	0.751	1 77	9	48	0.099
Consistency	Wilks Λ	0 766	1 63	9	48	0.135
Baseline	Wilks Λ	0 522	4 88	9	48	< 0.001*
Gender x Bolus Size	Wilks Λ	0 846	0 97	9	48	0 473
Gender x Consistency	Wilks Λ	0.811	1 24	9	48	0.292
Baseline x Gender	Wilks Λ	0.795	1 37	9	48	0.227
Bolus Size x Consistency	Wilks Λ	0 860	0 87	9	48	0 562
Baseline x Bolus Size	Wilks Λ	0 822	1 16	9	48	0.345
Baseline x Consistency	Wilks Λ	0.823	1 14	9	48	0 351
Consistency x Baseline x Gender	Wilks Λ	0 833	1 07	9	48	0 402
Bolus Size x Gender x Baseline	Wilks Λ	0 902	0 58	9	48	0 806
Bolus Size x Consisteocy x Gender	Wilks Λ	0 837	1 04	9	48	0.426
Baseline x Bolus Size x Consistency	Wilks Λ	0 747	1 81	9	48	0.091
Baseline x Gender x Bolus Size x Consistency	Wilks Λ	0 824	1 14	9	48	0.355

* indicates that the mean difference is significant at $\alpha = 0.05$

factors were then examined and also revealed nonsignificance (baseline x consistency *Wilks* $\Lambda = 0.823$, $F_{9,48} = 1.14$, $p = 0.351$; baseline x bolus size *Wilks* $\Lambda = 0.822$, $F_{9,48} = 1.16$, $p = 0.345$; bolus size x consistency *Wilks* $\Lambda = 0.860$, $F_{9,48} = 0.87$, $p = 0.562$; baseline x gender *Wilks* $\Lambda = 0.795$, $F_{9,48} = 1.37$, $p = 0.227$; gender x consistency *Wilks* $\Lambda = 0.811$, $F_{9,48} = 1.24$, $p = 0.292$; gender x bolus size *Wilks* $\Lambda = 0.846$, $F_{9,48} = 0.97$, $p = 0.473$). Therefore, the main effects were examined and revealed that baseline and gender significantly affect the combined dependent variable of PRT, HED, HAMRT, HAMD, THMD, CVPD, P-A score, HEDR, and HAMDR (baseline *Wilks* $\Lambda = 0.522$, $F_{9,48} = 4.88$, $p < 0.001$; gender *Wilks* $\Lambda = 0.350$, $F_{9,48} = 9.90$, $p < 0.001$). This combined dependent variable, however, was not significantly affected by bolus size (*Wilks* $\Lambda = 0.751$, $F_{9,48} = 1.77$, $p = 0.099$) or consistency (*Wilks* $\Lambda = 0.766$, $F_{9,48} = 1.63$, $p = 0.135$). Therefore, univariate ANOVAs and Tukey's post hoc tests were conducted as follow up tests to evaluate the effects of gender and baseline on the dependent variables. Prior to examining the ANOVA results, the alpha level was adjusted utilizing the Bonferroni adjustment described earlier. Consequently, the adjusted α level was determined to be $0.05/9 = 0.006$. Univariate ANOVA results, presented in Table 3-27, reveal that gender significantly differs only for HAMDR ($F_{1,56} = 56.72$, $p < 0.001$), whereas baseline significantly differs only for the dependent variables of P-A score ($F_{1,56} = 10.79$, $p = 0.002$) and HEDR ($F_{1,56} = 21.05$, $p < 0.001$). Post hoc tests, presented in Table 3-28, reveal that female participants displaced the hyoid more anteriorly (*mean* = 1.36) than male participants did (*mean* = 1.23), see Figure 3-20. They also revealed that both P-A score and HEDR measured during the post-treatment baseline ($P\text{-}A_{Post}$ *mean* = 1.13, $HEDR_{Post}$ *mean* = 0.92) were significantly lower than that measured during the

Table 3 27 A result summary table of the univariate ANOVAs conducted for 5 and 10cc swallow dependent variables

Source	Dependent Variable	DF	Type I SS	Mean Square	F value	P value
Model	PRT	23	20 338	0 884	1 29	0.219
	HED	23	1.217	0.053	1.01	0.469
	HAMRT	23	7 818	0.340	1.54	0.094
	HAMD	23	0.616	0 027	1.41	0 147
	THMD	23	14.781	0.643	1.62	0.073
	CVPD	23	67 046	2 92	0.96	0.522
	P A Score	23	5.519	0.240	1.57	0 087
	HEDR	23	0.059	0.003	3.92	< 0.001
	HAMDR	23	0.677	0.029	5.25	<0 001
Bolus Size	PRT	1	0.741	0 741	1.08	0.304
	HED	1	0.007	0.007	0 14	0.707
	HAMRT	1	0.794	0 794	3 61	0.063
	HAMD	1	0.015	0.015	0.78	0 381
	THMD	1	1 350	1 350	3.40	0.071
	CVPD	1	2.855	2.855	0.94	0 3355
	P-A Score	1	0 113	0 113	0.73	0395
	HEDR	1	0 001	0 001	1 20	0.279
	HAMDR	1	0.057	0.057	10.19	0.002
Consistency	PRT	1	1 545	1 545	2.25	0 139
	HED	1	0.011	0.011	0.21	0 649
	HAMRT	1	0 114	0 114	0.52	0 476
	HAMD	1	0 002	0.002	0 09	0 764
	THMD	1	0.034	0.034	0.09	0 771
	CVPD	1	3 088	3 088	1 02	0 317
	P A Score	1	0 003	0.003	0 02	0 887
	HEDR	1	0 005	0 005	7 87	0 007
	HAMDR	1	0 000	0.000	0 01	0 904
Baseline	PRT	1	0.004	0.004	0.01	0 936
	HED	1	0 057	0 057	1 09	0 302
	HAMRT	1	0.006	0 006	0 03	0 866
	HAMD	1	0 013	0 013	0 69	0 408
	THMD	1	0 063	0 063	0 16	0.692
	CVPD	1	2 904	2.904	0 96	0.332
	P A Score	1	1 653	1.653	10 79	0 002*
	HEDR	1	0 014	0.014	21 05	< 0.001*
	HAMDR	1	0 003	0 003	0.49	0 487
Gender	PRT	1	0 738	0 738	1 07	0 305
	HED	1	0 088	0 088	1 67	0 201
	HAMRT	1	0 046	0 046	0 21	0 651

	HAMD	1	0.148	0.148	7.79	0.007
	THMD	1	0.536	0.536	1.35	0.250
	CVPD	1	2.922	2.922	0.97	0.330
	P-A Score	1	0.602	0.602	3.93	0.052
	HEDR	1	0.002	0.002	3.14	0.082
	HAMDR	1	0.318	0.318	56.72	<0.001*
Bolus Size x Consistency	PRT	1	0.032	0.032	0.05	0.829
	HED	1	0.032	0.032	0.60	0.440
	HAMRT	1	0.087	0.087	0.40	0.531
	HAMD	1	0.003	0.003	0.16	0.691
	THMD	1	0.077	0.077	0.19	0.662
	CVPD	1	2.787	2.787	0.92	0.341
	P A Score	1	0.000	0.000	0.000	1.000
	HEDR	1	0.000	0.000	0.47	0.496
	HAMDR	1	0.000	0.000	0.01	0.919
Bolus Size x Baseline	PRT	1	0.237	0.237	0.34	0.560
	HED	1	0.036	0.036	0.68	0.413
	HAMRT	1	0.218	0.218	0.99	0.324
	HAMD	1	0.013	0.013	0.66	0.418
	THMD	1	0.013	0.013	0.03	0.860
	CVPD	1	3.001	3.001	0.99	0.324
	P A Score	1	0.313	0.313	2.04	0.159
	HEDR	1	0.001	0.001	1.12	0.295
	HAMDR	1	0.004	0.004	0.67	0.417
Consistency x Baseline	PRT	1	0.418	0.418	0.61	0.439
	HED	1	0.072	0.072	1.38	0.246
	HAMRT	1	0.002	0.002	0.01	0.916
	HAMD	1	0.046	0.046	2.42	0.126
	THMD	1	0.021	0.021	0.05	0.817
	CVPD	1	2.898	2.898	0.96	0.332
	P A Score	1	0.078	0.078	0.51	0.478
	HEDR	1	0.000	0.000	0.54	0.464
	HAMDR	1	0.000	0.000	0.04	0.844
Bolus Size x Gender	PRT	1	0.194	0.194	0.28	0.598
	HED	1	0.068	0.068	1.29	0.260
	HAMRT	1	0.095	0.095	0.43	0.513
	HAMD	1	0.046	0.046	2.42	0.126
	THMD	1	0.037	0.037	0.09	0.762
	CVPD	1	1.914	1.914	0.63	0.430
	P-A Score	1	0.033	0.033	0.22	0.643
	HEDR	1	0.001	0.001	1.38	0.245
	HAMDR	1	0.000	0.000	0.07	0.786
Consistency x Gender	PRT	1	0.298	0.298	0.43	0.513
	HED	1	0.135	0.135	2.58	0.114

	HAMRT	1	0.004	0.004	0.02	0.895
	HAMD	1	0.078	0.078	4.11	0.047
	THMD	1	0.814	0.814	2.05	0.158
	CVPD	1	1.773	1.773	0.59	0.447
	P A Score	1	0.075	0.075	0.49	0.487
	HEDR	1	0.003	0.003	4.61	0.036
	HAMDR	1	0.023	0.023	4.08	0.048
Gender x Baseline	PRT	1	0.073	0.073	0.11	0.745
	HED	1	0.024	0.024	0.47	0.498
	HAMRT	1	0.327	0.327	1.49	0.228
	HAMD	1	0.005	0.005	0.27	0.606
	THMD	1	0.552	0.552	1.39	0.243
	CVPD	1	2.120	2.120	0.70	0.406
	P A Score	1	0.300	0.300	1.96	0.167
	HEDR	1	0.000	0.000	0.31	0.582
	HAMDR	1	0.001	0.001	0.14	0.709
Bolus size x Consistency x Baseline	PRT	1	0.0784	0.0784	0.11	0.737
	HED	1	0.000	0.000	0.00	0.978
	HAMRT	1	0.209	0.209	0.95	0.334
	HAMD	1	0.011	0.011	0.56	0.459
	THMD	1	0.055	0.055	0.14	0.710
	CVPD	1	3.113	3.113	1.03	0.315
	P A Score	1	0.450	0.450	2.94	0.092
	HEDR	1	0.000	0.000	0.71	0.402
	HAMDR	1	0.015	0.015	2.74	0.104
Bolus size x Consistency x Gender	PRT	1	0.002	0.002	0.00	0.958
	HED	1	0.002	0.002	0.03	0.856
	HAMRT	1	0.015	0.015	0.07	0.793
	HAMD	1	0.068	0.068	3.57	0.064
	THMD	1	0.014	0.014	0.04	0.851
	CVPD	1	1.985	1.985	0.66	0.421
	P-A Score	1	0.469	0.469	3.06	0.086
	HEDR	1	0.001	0.001	1.52	0.223
	HAMDR	1	0.001	0.001	0.26	0.610
Bolus Size x Gender x Baseline	PRT	1	0.177	0.177	0.26	0.614
	HED	1	0.019	0.019	0.37	0.545
	HAMRT	1	0.550	0.550	2.50	0.120
	HAMD	1	0.001	0.001	0.07	0.797
	THMD	1	0.791	0.791	1.99	0.164
	CVPD	1	2.259	2.289	0.76	0.388
	P A Score	1	0.052	0.052	0.34	0.562
	HEDR	1	0.001	0.001	1.03	0.316
	HAMDR	1	0.000	0.000	0.00	0.988
	PRT	1	0.499	0.499	0.73	0.398

Consistency x Gender x Baseline	PRT	1	0.499	0.499	0.73	0.398
	HED	1	0.001	0.001	0.02	0.900
	HAMRT	1	1.071	1.071	4.87	0.032
	HAMD	1	0.004	0.004	0.24	0.629
	THMD	1	1.186	1.186	2.99	0.090
	CVPD	1	1.706	1.706	0.56	0.458
	P-A Score	1	0.052	0.052	0.34	0.562
	HEDR	1	0.000	0.000	0.15	0.702
	HAMDR	1	0.014	0.014	2.54	0.117
Bolus Size x Consistency x Gender x Baseline	PRT	1	2.084	2.084	3.03	0.087
	HED	1	0.058	0.058	1.12	0.295
	HAMRT	1	0.827	0.827	3.76	0.058
	HAMD	1	0.007	0.007	0.35	0.558
	THMD	1	1.066	1.066	2.68	0.107
	CVPD	1	1.728	1.728	0.57	0.453
	P-A Score	1	0.675	0.675	4.41	0.040
	HEDR	1	0.001	0.001	0.76	0.386
	HAMDR	1	0.010	0.010	1.81	0.184
Error	PRT	58	38.464	0.687		
	HED	56	2.933	0.052		
	HAMRT	58	12.324	0.220		
	HAMD	56	1.062	0.019		
	THMD	58	22.241	0.397		
	CVPD	56	169.406	3.025		
	P-A Score	56	8.578	0.153		
	HEDR	56	0.037	0.001		
	HAMDR	56	0.314	0.006		
Corrected Total	PRT	79	58.801			
	HED	79	4.150			
	HAMRT	79	20.142			
	HAMD	79	1.678			
	THMD	79	37.021			
	CVPD	79	236.452			
	P-A Score	79	14.097			
	HEDR	79	0.096			
	HAMDR	79	0.991			

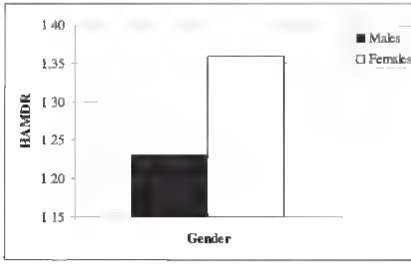
* indicates that the mean difference is significant at $\alpha = 0.006$

Table 3.28 Post hoc tests for the effects of Gender on HAMDR and Baseline on P A score and HEDR during 5 and 10cc swallows

Dependent Variable	Indapendent Variable Combinations (I)	(J)	Mean (I)	Mean (J)	Mean Difference (I-J)	Std. Error	P value
HAMDR	M	F	1.231	1.359	-0.128	0.017	<0.001*
P-A Score	Post	Pre	1.130	1.443	-0.313	0.089	0.001*
HEDR	Post	Pre	0.922	0.948	-0.026	0.006	<0.001*

* indicates that the mean difference is significant at α = 0.006

Figure 3-20 Effect of Gender on HAMDR.



pre-treatment baseline (PA $_{Pre}$ *mean* = 1.44, HEDR $_{Pre}$ *mean* = 0.95; see Figures 3-21 and 3-22.

Correlations Between MEP and Other Dependent Variables

A Pearson's test of correlation was conducted between MEP and the variables included in this study. Results presented in Table 3-29 reveal a significant, but weak positive correlation between improvements in MEP and PPPD ($r = 0.183$, $p = 0.030$). Positive significant correlations were relatively stronger for MEP with SWAL-QOL total score ($r = 0.431$, $p < 0.001$), IPD ($r = 0.545$, $p < 0.001$), and with PPPA ($r = 0.596$, $p < 0.001$). An even stronger significant positive correlation was found for MEP with PEFR ($r = 0.754$, $p < 0.001$). In contrast, significant but modest negative correlations were found between MEP and total UPRDS-M scores ($r = -0.321$, $p < 0.001$), FEV1/FVC ($r = -0.403$, $p < 0.001$). Stronger negative correlations were found for MEP with total 3oz swallow duration ($r = -0.544$, $p = 0.013$), HEDR ($r = -0.562$, $p < 0.001$), and number of swallows required to clear 3oz of thin liquid ($r = -0.618$, $p = 0.004$).

Reliability

A Pearson's test of correlation and a paired sample t-test were conducted to evaluate the intra-judge reliability in cough measures. Results presented in Table 3-30 reveal a very strong positive correlation between the measurements made twice by the same judge ($r = 0.993$). In addition, results of the t-test indicate no significant differences between the measurements ($p = 0.763$). Similar tests were conducted to evaluate the inter-judge reliability in cough measures. Results presented in Table 3-30 also indicate a very strong positive correlation between the measurements made by the two judges ($r = 0.969$), and that the measurements of the two judges were not significantly different from

Figure 21 Mean P A scores at different Baselines

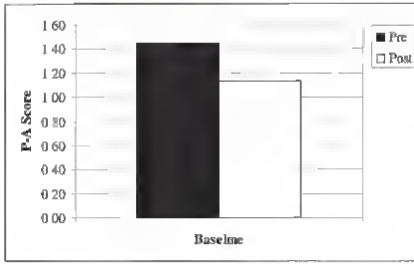


Figure 22 Mean HEDR at different Baselines.

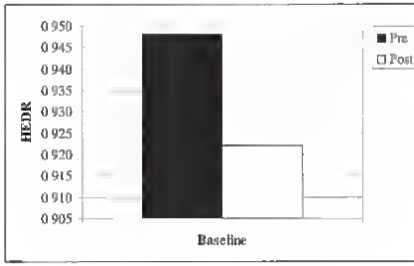


Table 3-29 Correlations between MEP and other dependent variables

Dependent Variables		r	P value
Pulmonary Function	FEV1/FVC	0.403	< 0.001*
	FEV1	- 0.012	0.889
	MEF	0.087	0.305
Cough Function	IPD	0.545	< 0.001*
	CPD	0.143	0.092
	PEFR	0.754	< 0.001*
	PPPD	0.183	0.030*
	PPPA	0.596	< 0.001*
3 oz Swallow	Swallow Duration	- 0.544	0.013*
	Number of Swallows	0.618	0.004*
5cc,10cc Swallows	PRT	- 0.156	0.166
	HED	0.203	0.071
	HAMRT	0.108	0.343
	HAMD	0.136	0.228
	THMD	0.190	0.091
	CVPD	0.027	0.812
	HEDR	- 0.562	< 0.001*
	HAMDR	- 0.077	0.498
	P A Score	- 0.137	0.175
SWAL-QOL Total		0.431	< 0.001*
Motor System	UPDRS-M Total	0.321	< 0.001*

* indicates that the mean difference is significant at a = 0.05

Table 3 30 Results of intra- and inter-judge reliability of cough and swallow measurements data.

Data	Reliability	Pearson's r	t-test's P value
Cough	Intra-Judge	0.993	0.763
	Inter Judge	0.969	0.754
Swallow Temporal	Intra Judge	0.927	0.776
	Inter Judge	0.911	0.684
Swallow Displacement	Intra Judge	0.936	0.972
	Inter Judge	0.971	0.941

each other ($p = 0.754$)

To investigate the intra-judge reliability of swallow temporal measures data, another Pearson's test of correlation and another equal variance t-test were conducted. Results, presented in Table 3-29, reveal the presence of a very strong positive correlation between the two measurements ($r = 0.927$) and the indifference between them ($p = 0.776$). Inter-judge reliability of swallow temporal data was also investigated using a Pearson's test of correlation and an equal-variance t-test. Results, presented in Table 3-30, reveal a very strong positive correlation between the measurements made by the two judges ($r = 0.911$). They also indicate that the difference between the two measurements were insignificant ($p = 0.684$).

Finally, the swallow displacement measures data were tested for intra- and inter-judge reliability using Pearson's tests of correlation and equal variance t tests. Results of intra-judge reliability tests, presented in Table 3-30, indicate a very strong positive correlation between the two measurements ($r = 0.936$) and that the difference between the two measurement was insignificant ($p = 0.972$). Results of inter-judge reliability tests, see Table 3-29, also indicate a very strong positive correlation between the measurements made by the two judges ($r = 0.971$) and that the difference between the two judges measurement was insignificant ($p = 0.941$).

CHAPTER 4
DISCUSSION

This was a phase I treatment outcome study evaluating the effects of an expiratory muscle strength training program (EMST) in patients with idiopathic Parkinson's disease. It investigated the effects that potential gains in expiratory muscle strength might have on pulmonary and cough functions. Additionally, the training program specifically targets suprahyoid muscle activity. Thus, another purpose was to determine the impact of EMST on the swallow function of patients with IPD. Finally, this study investigated the effects of antiparkinsonian medications on the pulmonary and cough functions.

Pulmonary Function

The results of this study indicate that a significant improvement was found in the expiratory muscle strength of patients with IPD following exposure to EMST. This finding concurs with other studies utilizing this program in healthy (Baker, 2003; Sapienza et al., 2002) and clinical populations (Chiara et al., 2003; Saptenza et al., 2001; Sapienza, 2002) and provided evidence of the training potential of expiratory muscles in patients with IPD. Further, this study found no significant effect of pharmacological treatments on the expiratory muscle strength of patients with IPD. While this finding is in agreement with the findings of Weiner et al. (2002), it contradicts those of DeBruin et al. (1993). This discrepancy may be due to differences in medications used among the studies. It could be further attributed to differences in participants' age and disease severity level. Compared to the current study (*mean* age = 59), the participants in the

Weiner et al (2002) study were older (*mean* age = 66) while those in the DeBruin et al. (1993) study were younger (*mean* age = 51). All the participants in the Weiner et al (2002) sample used Levodopa as their antiparkinsonian medication, whereas participants in the DeBruin et al (1993) sample only used Apomorphine (a dopamine agonist). Most of the participants in this study used a combination of Levodopa and a dopamine agonist. Therefore, the potential improvements in MEP with a dopamine agonist, as suggested by DeBruin et al (1993) might have been blocked by the conjunctional use of Levodopa by participants in this study. Nonetheless, this finding is non trivial as it may suggest the potential of non-dopaminergic, in addition to dopaminergic, pathway involvement in the pathogenesis of respiratory muscle weakness in patients with IPD. Specifically, these findings suggest that parkinsonian respiratory muscle weakness evidenced here, is not solely related to nigrostriatal dopamine deficiency and may be due to an addition non dopamine related disturbance of the central pattern generator for respiration in the pedunculopontine nucleus or related structures in the brainstem (see figure 1-3).

The gender differences found for expiratory muscle strength in this study were in accordance with those previously found for limb muscle strength (Morrow & Hosler, 1981, Powers & Howley, 2001). The current study found that male patients with IPD had significantly stronger expiratory muscles (approximately 36%) than females did. This gender effect is probably due to the larger cross-sectional area and therefore force production ability of the skeletal muscles in males compared to females (Powers & Howley, 2001). This effect of gender on expiratory muscles strength is similar to that reported for the skeletal muscles in the lower body (approximately 30%) but less than that found for the upper body (approximately 50%, Powers & Howley, 2001). However

the expiratory muscles of both genders responded similarly to the strength-training program with females gaining approximately 27% and males gaining approximately 33%. This finding is in agreement with those previously reported for limb skeletal muscles (Holloway & Baechle, 1990; O'Shea & Wagner, 1981; Wilmore, 1974).

The significant improvement in expiratory muscles strength following exposure to EMST resulted in improvements of some measures of pulmonary function, FEV1 and MEF. This may be due to improvements in expiratory muscle force generation in response to strength-training, similar to that reported for limb muscles (Hickson, 1980; Powers & Howley, 2001). Improvement in FEV1 without altering the FEV1/FVC ratio indicates that FVC was improved at the same rate as that of FEV1. Descriptive analysis showed similar improvements of FVC to that of FEV1, on the order of 8.5% increase pre- to post training. Improvements in FVC with EMST signify an increased lung capacity likely causing the improvements of FEV1. Improvements in FVC could be attributed to potential improvements in inspiratory muscle strength and/or activity with EMST. The potential strength gain of inspiratory muscles is conceivable since the activities performed during EMST require the repetitive activation (i.e., increased load) of the inspiratory muscles to reach a near total lung capacity. Further improvements in FVC could be attributed to gains in the inspiratory muscle activation since strength training programs are known to reduce the antagonistic muscles coactivation (Gibberd et al., 1981). Therefore, it is possible that although EMST is specific to the expiratory muscles, it has a potential secondary impact on the activity, strength, and function of the inspiratory muscles.

The improvements in FEV1 in patients with IPD may be beneficial in increasing their survival rate. Schunemann, Dorn, Grant, Winkelstein, and Trevisan (2000) found that higher FEV1 scores were negatively associated with mortality in healthy participants and could be used as a predictor for survival rates since FEV1 should result in better ability to clear the airway as well as improve the gas exchange rate. Similar findings were found by Neas and Schwartz (1998).

Antiparkinsonian medications failed to exert a significant change on any of the pulmonary function measures of this study, although they resulted in a significant 11% improvement in UPDRS-M total scores. The affects of antiparkinsonian medications on pulmonary function were consistent with the findings of Obenour et al. (1972) and Herer et al. (2001) and contradicted those reported by DeBruin et al. (1993), Nakano et al. (1972), and Vincken et al. (1989). As described earlier, participants in the DeBruin et al. (1993) study used dopamine agonists whose affect may be blocked by the conjunctional use of Levodopa. Therefore, their results might not be directly compared to those of this study. In contrast, both the Nakano et al. (1972) and Vincken et al. (1989) studies tested the effects of Levodopa on the pulmonary function of their participants. The Vincken et al. (1989) report, however, was of a single case with a reversible upper airway obstruction with Levodopa intake. Although carefully designed and analyzed, the results of Vincken et al. (1989) cannot be generalized to the pulmonary performance of patients with IPD after Levodopa intake. Nakano et al. (1972) investigated the effects of Levodopa intake on 23 patients with IPD, but failed to control for the effects of smoking (sample included 12 smokers) or the presence of other pulmonary diseases (present in 12

of their participants). Therefore, their reported improvements of pulmonary function as a result of Levodopa intake could not be isolated.

The lack of antiparkinsonian medications effect on pulmonary function reported by the current study supports the potential of non-dopaminergic, in addition to dopaminergic, pathways involvement in the pathogenesis of pulmonary dysfunction in patients with IPD. As described earlier, these findings suggest that parkinsonian pulmonary dysfunction, evidenced here, is not solely related to nigrostriatal dopamine deficiency and may be due to an additional non-dopamine related disturbance of the central pattern generator for respiration in the pedunculopontine nucleus or related structures in the brainstem (see figure 1-3).

Finally, male participants outperformed the females in the pulmonary function measures of FEV1 and MEF but not FEV1/FVC. This is consistent with reported gender differences among healthy individuals (e.g., Ashley, Kannel, Sorlie, & Masson, 1975; Chen & Kuo, 1989; Schwartz, Katz, Fegley, & Tockman, 1988).

Cough Function

Cough measures were differentially affected by EMST, gender, and antiparkinsonian medications. Inspiratory phase duration was significantly reduced with EMST. Reductions in inspiratory duration following EMST are consistent with findings of an earlier study utilizing this program in healthy individuals (Baker, 2003), and signify the ability of the expiratory muscles to produce a sufficient airflow rate utilizing less inspiratory lung volume.

Antiparkinsonian medications resulted in a longer inspiratory duration in the medication ON state. Recall, there were no significant effects of antiparkinsonian

medications on any of the pulmonary function measure described earlier suggesting that chestwall rigidity is unchanged by the medications The result for inspiratory duration was not congruent with the anticipated results of medication intake While other hypotheses about central inhibitions and activity of other muscles such as those in the larynx could be postulated, the fact that this study did not examine activity of the larynx would make these speculations premature.

Males had longer inspiratory durations than females did. This may be caused by the previously reported relatively larger FVC in males than females. A larger FVC may require a longer inspiratory phase to reach a sufficient inspiratory lung volume for the compression phase to commence

As for compression phase duration, a significant interaction between the training and gender occurred. This was characterized by no change in compression phase duration for males with EMST Females on the other hand had significant progressive declines in compression phase durations with training However this decline cannot be totally attributed to EMST because the pre-training multiple baseline outcome for compression phase duration produced by the females was inconsistent. In order to examine this variability in gender performance during cough production the status of the laryngeal adductors like the lateral cricoarytenoid (LCA) and the interarytenoid (IA) muscles should be examined concurrently This would help determine the normality of their activity If the primary laryngeal adductors are functioning normally then the lack of alteration to the compression phase duration would be expected. Antiparkinsonian medications had no significant effect on compression phase duration

The PEFR was affected by EMST for the males. It was significantly higher for males post-treatment from that measured during the second pre-treatment baseline but not the first one. This difference could be attributed to inconsistencies in the behavior of the male patients with IPD since the measurement made during the second pre-treatment baseline was not significantly different from that made during the first pre-treatment baseline. Assuming PEFR was positively affected by EMST for the males, this would be likely due to higher force generation of the expiratory muscles, thus resulting in higher airflow rates. PEFR was unaffected by EMST for the females and is most likely due to the smaller size of the female airway limiting the peak expiratory flow rate even in the presence of higher expiratory force generation.

Antiparkinsonian medications reduced PEFR. Since the expiratory muscles were unaffected by these medications, this negative effect could be attributed to the possible interference effect the medications might have on the laryngeal muscles. This was alluded to earlier under the discussion for inspiratory phase duration. While a speculation, PEFR may be reduced by an incomplete contraction of the laryngeal abductor muscles or incomplete relaxation of the laryngeal adductor muscles. Since the laryngeal adductors appear to be functioning normally during the compression phase, the possible implication of the negative effects of medications on PCA is of interest but requires further study. Finally, because all measures were made first in the OFF medication state followed by the ON medication state, the effect of fatigue cannot be ruled out.

No significant effect was found for EMST on the measure of PPPD. This indicates that changes induced by EMST could not alter the ability of the expiratory

muscles to sustain their generated force. This is consistent with the findings of improved force generation but not endurance of the limb skeletal muscles in response to strength training programs (Powers & Howley, 2001).

A significant gender effect was found on PPPD with males having longer PPPDs than females. This is likely attributed to the greater forced expiratory muscle activity of males, which was demonstrated in their significantly higher FEV1 measure compared to females. However, this result cannot be interpreted in isolation from PPPA, since longer duration with increased amplitude would be of the most benefit for clearing the airway.

Antiparkinsonian medications had no significant effect on PPPD. The duration of the PPPD is mainly attributed to the activities of the expiratory muscles. The lack of antiparkinsonian medications effect on PPPD demonstrated here is similar to the lack of medications effect reported earlier for pulmonary functions. It also supports the potential of non-dopaminergic in addition to dopaminergic pathways involvement in the pathogenesis of pulmonary dysfunction in patients with IPD. As described earlier, these findings suggest that parkinsonian pulmonary dysfunction evidenced here is not solely related to nigrostriatal dopamine deficiency and may be due to an additional non dopamine related disturbance of the central pattern generator for respiration in the pedunculopontine nucleus or related structures in the brainstem (see figure 1-3).

A three-way interaction was found for PPPA among baseline (EMST), gender and medication. Results of PPPA indicate that although inconsistent, males had higher PPPA than females. Therefore, males were able to sustain the post-peak airflow at higher amplitudes and for longer times than females did. This could be attributed to differences between the two genders in expiratory muscle strength and their force generation abilities

(Ashley et al., 1975, Chen & Kuo 1989, Schwartz et al., 1983). The effects of antiparkinsonian medications were relatively trivial as PFPA did not respond differently in the OFF and ON medication states. Although inconsistent, PPPAs were higher for some participants following EMST while PPPD was unchanged. This indicates that changes induced by EMST could be the result of improved force generation abilities of the expiratory muscles, but not the ability to sustain that force. This is consistent with the findings of improved force generation but not endurance of the limb skeletal muscles in response to strength training programs (Powers & Howley, 2001).

Swallow Function

There was no significant training effect on the 3 oz. swallow function. It is possible that a ceiling effect is being reached as the participants' swallow function were mildly impaired, and a population sample with more severely impaired swallow function could better reveal the full potential of EMST as a rehabilitative program of the swallow function in patients with IPD.

The results of the 3oz thin liquid sequential swallow indicated only a significant effect for gender as female participants took a longer time to clear the 3oz swallow with more sequential swallows than males did. This could be simply explained by the known larger anatomical dimensions of the vocal tract in men such as larger cross-section of the pharynx (Brooks & Strohl, 1992) allowing for larger bolus intake than females and requiring shorter time and less number of sequential swallows to clear a constant volume. In contrast, all temporal measures of 5 and 10cc boluses in both consistencies were not significantly affected by baseline and gender. Recall that the medication status was not compared for swallowing measures.

The displacement measure of hyoid elevation on the other hand indicated larger superior displacement following EMST This increased displacement post treatment was achieved in the same duration as that measured pre-treatment. This finding, therefore attested that the hyoid moved at a higher velocity in the superior direction following EMST Many underlying physiological mechanisms could have attributed to this finding Forced expiration is associated with superior movement of the larynx that could be caused by either increased superior tracheal pull or the contraction of the suprahyoid muscles (Fink & Demarest 1978 Korkko 1993) It is possible therefore that this increased activation of these muscles as a result of the EMST task could have resulted in their improved force generation abilities, inducing the observed faster movement of the hyoid. Other hypotheses, however, cannot be ignored. Indeed, high airflow rates generated during EMST might have resulted in increased activation of the lingual and oropharyngeal mechanoreceptors, which has the potential of increasing the activation of the nucleus tractus solitarius and, in turn the nucleus ambiguous and its associated motor units Conceivably this could result in improved activation of the pharyngeal swallow pattern and its musculature. However, since no changes were observed for the pharyngeal swallow temporal measures following EMST, it is possible that this hypothesis is not operational under these conditions No significant gender effect was found on HEDR

An important functional finding of the effects of EMST on the swallowing of patients with IPD was the significant improvement in P-A score following exposure to EMST This finding reveals that the physiological mechanisms activated by EMST resulted in improved protection of the airway The three hypotheses described earlier to

explain the increased hyoid displacement could also be postulated for this improvement in P A score. Likewise improvements in P A score however could be the result of increased activation of the lateral cricoarytenoid muscle (LCA a laryngeal adductor muscle) induced by increased lung volume during EMST (Koizumi et al 1996) Increased activation of the LCA improves laryngeal closure and could have contributed to the reduction in laryngeal intrusion observed following EMST No gender effect was found effect as predicted

A note about the use of the displacement ratios is applicable at this juncture The displacement ratios used to measure the hyoid movements in this study were used as indirect measures of the hyoid movement magnitude These measures were used to counter the potential effects of image zoom variations among swallows Actual displacement measures could be used in future studies if a correction factor could be included utilizing the presence of an object of known parameters in the captured swallow images In addition the trajectory of the produced movements might be worth exploring to identify the temporal progress of these movements and the possible associations of these movements with other temporal events in the swallow process

Summary

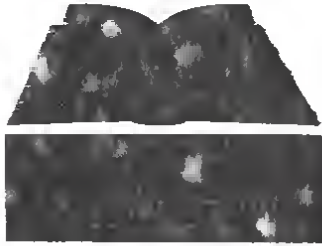
Overall, this study provided the results of a phase I clinical outcome research (Robey & Schultz, 1998) investigating the therapeutic effects of EMST on pulmonary, cough, and swallow functions. It further provided a Class II level of evidence (American Academy of Neurology, 1994) of the therapeutic effects of EMST in patients with IPD It represented an essential step towards exploring the potential of EMST as an efficacious rehabilitative program for the respiratory muscles in patients with IPD Although

therapeutic effects were detected by this study, preliminary investigations are still needed to establish the optimum duration of EMST to elicit the best therapeutic effect. The duration utilized in this study was four weeks. The therapeutic effects observed as a result of EMST in this short period could mainly be attributed to the physiological mechanisms of neural adaptations (Sale, 1988). Further investigations are needed to explore the sites of these adaptations by investigating the potential relative involvement of the aforementioned cortical and peripheral mechanisms in the emergence of the therapeutic effects. Longer durations of EMST could also be investigated, and the underlying physiological mechanisms of their therapeutic effects if achieved, require further research. In addition, preliminary work is needed to investigate EMST effects on more severe cases of IPD to explore the full potential of this rehabilitation program. Finally, the long-term effects of EMST as a therapeutic, efficacious home based rehabilitative program could be investigated. Its effects in conjunction with other programs are worth exploring.

Although pharmacological effects were trivial on the functions tested prior to EMST their effects might be considerable and worth exploring on a group of patients with more severe Parkinson's disease. The lack of medication effect in the group studied in this project could lend support to the potential of non-dopaminergic, in addition to dopaminergic, pathways involvements in the pathogeneses of respiratory and cough difficulties in patients with IPD. It is also consistent with the view that the dopaminergic system affects systems in varying degrees, probably as a result that a defective motor circuit could have on its interaction with other neural circuits and structures (DeLong,

1990 Vitek, 1997 see Chapter One) These interactions are complex and require careful examination of their effects on the functions investigated in the current study

The SWAL-QOL SURVEY



Instructions for Completing the SWAL-QOL Survey

This questionnaire is designed to find out how your swallowing problem has been affecting your day-to-day quality of life.

Please take the time to carefully read and answer each question. Some questions may look like others, but each one is different.

Here's an example of how the questions in the survey will look.

In the last month how often have you experienced each of the symptoms below

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
Feel weak	1	2	3	4	5

Thank you for your help in taking part in this survey!

IMPORTANT NOTE: We understand that you may have a number of physical problems. Sometimes it is hard to separate these from swallowing difficulties but we hope that you can do your best to concentrate only on your ***swallowing problem.*** Thank you for your efforts in completing this questionnaire.

Below are some general statements that people with ***swallowing problems*** might mention. In the last month, how true have the following statements been for you.

(circle one number on each line)

	Very much true	Quite a bit true	Somewhat true	A little true	Not at all true
Dealing with my swallowing problem is very difficult	2	3	4	5	
My swallowing problem is a major distraction in my life	2	3	4	5	

Below are aspects of day-to-day eating that people with ***swallowing problems*** sometimes talk about. In the last month, how true have the following statements been for you?

(circle one number on each line)

	Very much true	Quite a bit true	Somewhat true	A little true	Not at all true
Most days I don't care if I eat or not	1	2	3	4	5
It takes me longer to eat than other people	1	2	3	4	5
I'm rarely hungry anymore	1	2	3	4	5
It takes me forever to eat a meal	1	2	3	4	5
I don't enjoy eating anymore	1	2	3	4	5

Below are some physical problems that people with ***swallowing problems*** sometimes experience. In the last month, how often you have experienced each problem as a result of your swallowing problem

(circle one number on each line)

	Almost always	Often	Sometimes	Hardly ever	Never
Coughing	2	3	4		5
Choking when you eat food	2	3	4		5
Choking when you take tablets	2	3	4		5
Having thick saliva or phlegm	2	3	4		5
Gagging	2	3	4		5
Retching	2	3	4		5
Problems chewing	2	3	4		5
Having excess saliva or phlegm	2	3	4		5
Having to clear your throat	2	3	4		5
Food sticking in your throat	2	3	4		5
Food sticking in your mouth	2	3	4		5
Food or liquid dribbling out of your mouth	2	3	4		5
Food or liquid coming out your nose	2	3	4		5
Coughing food or liquid out of your mouth when it gets stuck	2	3	4		5

4 Next, please answer a few questions about how your ***swallowing problem*** has affected your diet and eating in the last month

(circle one number on each line)

	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
Figuring out what I can and can't eat is a problem for me	1	2	3	4	5
It is difficult to find foods that I both like and can eat.	1	2	3	4	5

In the last month, how often have these statements about communication applied to you because of your *swallowing problem*?

circle one number on each line

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
People have a hard time understanding me	1	2	3	4	5
It's been difficult for me to speak clearly	1	2	3	4	5

Below are some concerns that people with *swallowing problems* sometimes mention. In the last month, how often have you experienced each feeling?

circle one number on each line

	Almost always	Often	Sometimes	Hardly ever	Never
I fear I may start choking when I eat food	1	2	3	4	5
I worry about getting pneumonia	1	2	3	4	5
I am afraid of choking when I drink liquids	1	2	3	4	5
I never know when I am going to choke	1	2	3	4	5

In the last month, how often have the following statements been true for you because of your *swallowing problem*?

(circle one number on each line)

	Always true	Often true	Sometimes true	Hardly ever true	Never true
My swallowing problem depresses me	1	2	3	4	5
Having to be so careful when I eat or drink annoys me	1	2	3	4	5
I've been discouraged by my swallowing problem	1	2	3	4	5
My swallowing problem frustrates me	1	2	3	4	5
I get impatient dealing with my swallowing problem	1	2	3	4	5

Think about your social life in the last month. How strongly would you agree or disagree with the following statements?

(circle one number on each line)

	Strongly agree	Agree	Uncertain	Disagree	Strongly disagree
I do not go out to eat because of my swallowing problem		2	3	4	5
My swallowing problem makes it hard to have a social life		2	3	4	5
My usual work or leisure activities have changed because of my swallowing problem		2	3	4	5
Social gatherings like potlucks or get-togethers are no enjoyable because of my swallowing problem		2	3	4	5
My role with family and friends has changed because of my swallowing problem		2	3	4	5

In the last month, how often have you experienced each of the following physical symptoms?

(circle one number on each line)

	All of the time	Most of the time	Some of the time	A little of the time	None of the time
Feel weak?	1	2	3	4	5
Have trouble falling asleep?	1	2	3	4	5
Feel tired?	1	2	3	4	5
Have trouble staying asleep?	1	2	3	4	5
Feel exhausted?	1	2	3	4	5

*10 Do you now take any food or liquid through a feeding tube?

(circle one)

No 1

Yes 2

*11 Please circle the letter of the one description below that best describes the consistency or texture of the food you have been eating most often in the last week.

Circle one.

A **Circle this one** if you are eating a full normal diet which would include a wide variety of foods including hard to chew items like steak carrots bread salad and popcorn

B. **Circle this one** if you are eating soft, easy to chew foods like casseroles, canned fruits soft cooked vegetables ground meat, or cream soups

C. **Circle this one** if you are eating food that is put through a blender or food processor or anything that is like pudding or pureed foods

D. **Circle this one** if you take most of your nutrition by tube but sometimes eat ice cream, pudding apple sauce or other pleasure foods

E. **Circle this one** if you take all of your nourishment through a tube

12. Please **circle the** letter of the one description below that best describes the consistency of liquids you have been drinking most often in the last week.

Circle one

A. Circle this if you drink liquids such as water, milk, tea, fruit juice, and coffee

B. Circle this if the majority of liquids you drink are thick like tomato juice or apricot nectar. Such thick liquids drip off your spoon in a slow steady stream when you turn it upside down

C. Circle this if your liquids are moderately thick, like a thick milkshake or smoothie. Such moderately thick liquids are difficult to suck through a straw, like a very thick milkshake, or drip off your spoon slowly drop by drop when you turn it upside down, such as honey

D. Circle this if your liquids are very thick, like pudding. Such very thick liquids will stick to a spoon when you turn it upside down, such as pudding

E. Circle this if you do not take any liquids by mouth or if you have been limited to ice chips

13. In general, would you say your health is

(circle one)

Poor 1

Fair 2

Good 3

Very Good 4

Excellent 5

General Questions About You

What is the date of your birth?

Please write in your date of birth here: _____ month _____ day _____ year

What is your age today? _____

Are you –

(circle one)

Male 1

Female 2

What is your main racial or ethnic group?

(circle one)

White or Caucasian but not Hispanic or Latino 1

Black or African-American but not Hispanic or Latino 2

Hispanic or Latino 3

Asian 4

Other 5

What is the highest year of school or college you have ever completed?

(circle one number)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	16+
Grade School								High School				College				Post Graduate

What is your current marital status?

(circle one)

Never married 1

Married 2

Divorced 3

Separated 4

Widowed 5

Did anybody help you complete this questionnaire?

(circle one)

No, I did it myself 1

Yes, someone helped me fill it out 2

IF SOMEONE HELPED YOU FILL OUT THIS QUESTIONNAIRE, how did that person help you?

(circle one)

Read you the questions and/or wrote down the answers you gave 1

Answered the questions for you 2

Helped in some other way 3

Please write today's date here ____/____/____

month day year

Last Page

COMMENTS.

Do you have any comments about this questionnaire? We welcome your comments about the questionnaire in general or about specific questions, especially any that were unclear or confusing to you.

Thank you for completing this questionnaire!

APPENDIX B
WRITTEN TRAINING INSTRUCTIONS TO PARTICIPANTS

RESPIRATORY MUSCLE TRAINING PROGRAM

INSTRUCTIONS

The most important number to remember throughout this training period is the number **5** You will complete this training program **5** days per week. You will complete **5** sets of the exercises with **5** repetitions each time you complete your training

You have been given a respiratory trainer to complete your training at home. You will use this same trainer for the entire time that you are participating in this study

FIRST WEEK OF TRAINING

1 Place the nose clip on your nose

2 Breathe in as much air as you can and place the mouth piece in your mouth.

3 As soon as the mouth piece is in your mouth breathe out as much air as you can.
- keep a tight seal with your mouth around the mouth piece
- when the expiratory pressure is strong enough to open the valve, you will hear a rush of air move through the device

4 Repeat this expiratory exercise **5** times (steps 1-4) resting for 30 seconds to 1 minute in between each inspiration

5 When you have finished all **5** expirations rest for 2 minutes (you have completed 1 set)

6 After you have rested for 2 minutes repeat steps 1 – 5 (the **5** repetitions)

7 You will continue with this pattern of **5** expirations and 2 minute breaks until you have completed the **5** expirations procedure **5** times (now you have completed **5** sets)

8 On your training log, record the date and the time you completed these exercises

9 You will need to complete steps 1-9 **5** times during the week

10 At the end of this training week, you will have an appointment during which your maximum expiratory pressure will be taken and your respiratory trainer will be reset.

SECOND, THIRD, AND FOURTH WEEK OF TRAINING

During the second, third, and fourth week of training, you will follow the procedures described for the first week.

APPENDIX C
COMPLIANCE LOG SHEETS OF PARTICIPANT TRAINING

Participant: ID

Pressure Threshold Training
Training Log

Week 1

Time of last meds intake Time Now

Start Date	MEP 1	MEP2	MEP3	Avg MEP	Trainer Setting
–	MIP1	MIP2	MIP3	Avg MIP	–

Date	Time	SET 1 (5 breaths)	SET 2 (5 breaths)	SET 3 (5 breaths)	SET 4 (5 breaths)	SET 5 (5 breaths)

Participant. ID

Week 2

Time of last meds intake: Time Now:

Start Date	MEP1	MEP2	MEP3	Avg MEP	Trainer Setting
	MIP1	MIP2	MIP3	Avg MIP	–

Date	Time	SET 1 (5 breaths)	SET 2 (5 breaths)	SET 3 (5 breaths)	SET 4 (5 breaths)	SET 5 (5 breaths)

Week 3

Time of last meds intake: Time Now:

Start Date	MEP1	MEP2	MEP3	Avg MEP	Trainer Setting
–	MIP1	MIP2	MIP3	Avg. MIP	–

Date	Time	SET 1 (5 breaths)	SET 2 (5 breaths)	SET 3 (5 breaths)	SET 4 (5 breaths)	SET 5 (5 breaths)

Participant: ID

Week 4

Time of last meds intake Time Now

Start Date	MEP1	MEP2	MEP3	Avg MEP	Trainer Setting
–	MIP1	MIP2	MIP3	Avg MIP	–

Date	Time	SET 1 (5 breaths)	SET 2 (5 breaths)	SET 3 (5 breaths)	SET 4 (5 breaths)	SET 5 (5 breaths)

REFERENCES

Adams, G. R., Hather, B. M., Baldwin, K. M., & Dudley, G. A. (1993). Skeletal muscle myosin heavy chain composition and resistance training. *Journal of Applied Physiology*, 74, 911-15.

Alderson, A.M., & Downman, C. B. B. (1966). Supraspinal inhibition of thoracic reflexes of somatic and visceral origin. *Arch. Ital. Biol.*, 104, 309.

Alexander, G. E., DeLong, M. R., & Strick, P. L. (1986). Parallel organization of functionally segregated circuits linking basal ganglia and cortex. *Annual Reviews of Neuroscience*, 9, 357-81.

American Academy of Neurology (1994). Assessment: Melodic intonation therapy [Special article]. *Neurology*, 44, 566-568.

Amri, M., & Car, A. (1982). Projections from the medullary swallowing center to the hypoglossal motor nucleus: A neuroanatomical and electrophysiological study in sheep. *Brain Research*, 441, 319.

Amri, M., Car, A., & Jean, A. (1984). Medullary control of the pontine swallowing neurons in sheep. *Experimental Brain Research*, 55, 105.

Amri, M., Car, A., & Roman, C. (1990). Axonal branching of medullary swallowing neurons projecting on the trigeminal and hypoglossal motor nuclei: Demonstration by electrophysiological and fluorescent double labeling techniques. *Experimental Brain Research*, 81, 384.

Ashley, F., Kannel, W. B., Sorlie, P. D., Masson, R. (1975). Pulmonary function: relation to aging, cigarette habit, and mortality. *Ann Intern Med*, 82(6), 739-45.

Athlin, E., Norberg, A., Axelsson, K., Moller, A., & Nordstrom, G. (1989). Aberrant eating behavior in elderly Parkinsonian patients with and without dementia. *Research in Nursing & Health*, 12, 41-51.

Bach, J. R., Smith, W. H., Saporito, L., Alba, A. S., Dayal, R., & Pan, J. (1993). Airway secretion clearance by mechanical exsufflation for post poliomyelitis ventilator assisted individuals. *Archives of Physical Medicine and Rehabilitation*, 74, 170-177.

Baker, S.E (2003) *Expiratory Muscle Strength Training and Detraining: Effects on Speech and Cough Production.* Doctoral dissertation University of Florida

Baker, S.E Sapienza, C.M Brown, S Rothman, H., & Davenport, P (2002) Expiratory muscle strength training: Effects on cough and speech. A poster presentation in the American Speech Language-Hearing Association Annual Convention

Bassotti, G , Germani, U., Pagliaricci, S., Plesa, A., Giulietti, O Mannarino, E., & Morelli, A (1998) Esophageal manometric abnormalities in Parkinson's disease *Dysphagia*, 13 28-31

Belman M.J (1993) Exercise in patients with chronic obstructive pulmonary disease *Thorax*, 48(9) 936-46

Beradelli, A., Rothwell, J.C., Thompson, P.D., & Hallet, M. (2001) Pathophysiology of bradykinesia in Parkinson's disease *Brain*, 124 2131-2146.

Bianchi, A.L., Denavit-Sanbie, M., & Champagnat, J (1995) Central control of breathing in mammals Neuronal circuitry membrane properties and neurotransmitters *Physiological Review* 75, 1

Bianchi, A.L. & Pasaro, R (1997) Organization of central respiratory neurons In Miller, A.D., Bianchi, A.L., & Bishop, B.P. (Eds.) *Neural Control of the Respiratory Muscles.* CRC Press Boca Raton, FL.

Bieger, D (1991) Neuropharmacologic correlates of deglutition Lessons from fictive swallowing *Dysphagia*, 6, 147

Bird, M.R Woodward, M.C., Gibson, E.M., Phyland, D.J., & Fonda, D (1994) Asymptomatic swallowing disorders in elderly patients with Parkinson's disease. A description of findings on clinical examination and videofluoroscopy in sixteen patients *Age and Aging*, 23, 251-254

Bisch, E.M Logemann, J.A., Rademaker, A.W., Kahrilas, P.J., & Lazarus, C.L (1994) Pharyngeal effects of bolus volume, viscosity, and temperature in patients with dysphagia resulting from neurologic impairment and in normal subjects *Journal of Speech and Hearing Research*, 37(5) 1041-59

Bisgard, G.E Kressin, N.A., Nielsen, A.M., Damstotle, L., Smith, C.A., & Forster, H.V (1987) Dopamine blockade alters ventilatory acclimatization to hypoxia in goats *Respiratory Physiology*, 69 245

Bishop, B.P (1997) The abdominal muscles In Miller, A.D., Bianchi, A.L., & Bishop, B.P (Eds.) *Neural Control of the Respiratory Muscles.* CRC Press

Boca Raton FL

Blonsky E R , Logemann J.A Boshes B & Fisher H.B (1975) Comparison of speech and swallowing function in patients with tremor disorders and in normal geriatric patients A cinefluorographic study *Journal of Gerontology* 30, 299-303

Bogaard, J M Hovestadt, A., Meerwaldt, J van der Meché F G.A., & Stigt, J (1989). *American Review of Respiratory Diseases, 139* 610-614

Boshes B (1966) Voice changes in Parkinsonism *Journal of Neurosurgery 24* 286-290

Brasil-Neto J P Cohen L G & Hallett M (1994) Central fatigue as revealed by postexercise decrement of motor evoked potentials *Muscle Nerve* 17(7) 713-9

Brooks L.J & Strohl K P (1992) Size and mechanical properties of the pharynx in healthy men and women *American Review of Respiratory Diseases* 146(6), 1394-7

Brown, P (1997) Muscle sounds in Parkinson's disease *The Lancet*, 349, 533 535

Brown P Salenius S Rothwell J C , & Hari R (1998) Cortical correlate of the piper rhythm in humans *Journal of Neurophysiology* 80 2911-2917

Bulow M Olsson R & Ekberg O (2003) Videoradiographic analysis of how carbonated thin liquids and thickened liquids affect the physiology of swallowing in subjects with aspiration on thin liquids *Acta. Radiol* 44(4) 366 72

Bushman M Bomeyer, S M Leeker L. & Perlmutter, J S (1989) Swallowing abnormalities and their response to treatment in Parkinson s disease *Neurology* 39(10) 1309-1314

Calne D B (1994) Early idiopathic Parkinsonism Initiation and optimization of treatment *Clinical Neuropharmacology* 17(Suppl 2) S14-S18

Calne D B Shaw D G Spiers A S & Stern, G M (1970). Swallowing in Parkinsonism. *British Journal of Radiology 43(511)* 456-7

Canter, G J (1963) Speech characteristics of patients with Parkinson's disease I Intensity pitch and duration *Journal of Speech and Hearing Disorders 28(3),* 221-229

Canter G.J (1965) Speech characteristics of patients with Parkinson's disease II Physiological support for speech *Journal of Speech and Hearing Disorders 30(3),* 217-224

Carlson, N R. (2001). *Physiology of Behavior*. Allyn and Bacon: Needham Heights, Massachusetts.

Carpenter, D O. (1989). Central nervous system mechanisms in deglutition and emesis. In: Wood, J D. (Ed.). *Handbook of Physiology: The Gastrointestinal System*. Vol. I. American Physiological Society: Bethesda, MD.

Casaburi, R. (1994). Physiologic responses to training. *Clinical Chest Medicine*, 15(2), 215-27.

Castell, J A., Johnston, B T., Colchen, A., Li, Q., Gideon, R M., & Castell, D O. (2001). Manometric abnormalities of the oesophagus in patients with Parkinson's disease. *Neurogastroenterology and Motility*, 13(4), 361-364.

Champagnat, J., Denavit-Saubie, M., Henry, J.L., & Leviel, V. (1979). Catecholaminergic depressant effects on bulbar respiratory mechanism. *Brain Research*, 160, 57.

Chen, H.I., Kuo, C S. (1989). Relationship between respiratory muscle function and age, sex, and other factors. *Journal of Applied Physiology*, 66(2), 943-8.

Chiara, T., Martin, D., Sapienza, C.M., & Bolser, D. (2003). Expiratory muscle strength training in individuals with multiple sclerosis and healthy controls. College of Health Professions Poster Presentation Competition. University of Florida.

Coleridge, H M., & Coleridge, J C. (1994). Pulmonary reflexes: neural mechanisms of pulmonary defense. *Annual Review of Physiology*, 56, 69.

Cooley, R N., & Donner, M W. (1966). Cinefluorographic analysis of pharyngeal swallowing in neuromuscular disorders. *American Journal of Medical Sciences*, 251, 600-616.

Corcos, D.M., Chen, C M., Quinn, N P., McAuley, J., & Rothwell, J C. (1996). Strength in Parkinson's disease: Relationship to rate of force generation and clinical status. *Annals in Neurology*, 39(1), 79-88.

Cornford, M E., Chang, L., & Miller, B.L. (1995). The neuropathology of Parkinsonism. An overview. *Brain & Cognition*, 28(3), 321-41.

Cotzias, G.C., Papavasiliou, P S., & Gellene, R. (1969). Modification of Parkinsonism – chronic treatment with L-dopa. *New England Journal of Medicine*, 280, 337-345.

Dantas, R O., & Dodds, W.J. (1990). Effects of bolus volume and consistency on swallow-induced submental and infrahyoid electromyographic activity. *Braz. J. Med. Biol. Res.*, 23(1), 37-44.

Dantas, R.O., Kern, M.K., Massey, B.T., Dodds, W.J., Kahrilas, P.J., Brasseur, J.G., Cook, I.J., & Lang, I.M. (1990). Effects of swallowed bolus variables on oral and pharyngeal phases of swallowing. *American Journal of Physiology*, 258(5 Pt 1), G675-81.

DaSilva, A.M.T., Hartley, B., Hamesh, P., Quest, J.A., & Gillis, R.A. (1987). Respiratory depressant effects of GABAa and GABAb receptor agonists in the cat. *Journal of Applied Physiology*, 62, 2264.

De Bruin, P.F., De Bruin, V.M., Lees, A.J., & Pride, N.B. (1993). Effects of treatment on airway dynamics and respiratory muscle strength in Parkinson's disease. *American Reviews of Respiratory Disease*, 148(6 Pt 1),1576-80.

De La Torre, R., Mier, M., & Bosches, B. (1960). Studies in Parkinsonism. 9. Evaluation of respiratory function-preliminary observations. *Quarterly Bulletin of the Northwestern University Medical School*, 34, 232-6.

DeLong, M.R. (1990). Primate models of movement disorders of basal ganglia origin. *Trends in Neurosciences*, 13(7), 281-5.

Denavit-Saubié, M., & Foutz, A.S. (1997). Neuropharmacology of respiration. In: Miller, A.D., Bianchi, A.L., & Bishop, B.P. (Eds.). *Neural Control of the Respiratory Muscles*. CRC Press: Boca Raton, FL.

Den Hartog Jager, W.A., & Bethlem, J. (1960). The distribution of Lewy bodies in the central and autonomic nervous systems in idiopathic paralysis agitans. *Journal of Neurology, Neurosurgery, & Psychiatry*, 23, 283-90.

Dick, T.E., Oku, Y., Romaniuk, J.R., & Cherniack, N.S. (1993). Interaction between central pattern generators for breathing and swallowing in the cat. *Journal of Physiology*, 465, 715.

Dickinson, P.S., & Moulins, M. (1992). Interactions and combinations between different networks in the stomatogastric nervous system. In: Harris-Warrick, R.M., Marder, E., Selverston, A.I., & Moulins, M. (Eds.). *Dynamic Biological Network. The Stomatogastric Nervous System*. MIT Press: Cambridge.

Ding, R., Logemann, J., Larson, C., & Rademaker, A. (2003). The effects of taste and consistency on swallow physiology in younger and older healthy individuals: A surface electromyographic study. *Journal of Speech Language and Hearing Research*, 46(4), 977-89.

Dodds, W.J., Man, K.M., Cook, I.J., Kahrilas, P.J., Stewart, E.T., & Kern, M.K. (1988). Influence of bolus volume on swallow induced hyoid movement in normal subjects. *Amer J Roentgenol*, 150(6), 1307-9.

Donner, M. & Silbiger, M. (1966) Cinefluorographic analysis of pharyngeal swallowing in neuromuscular disorders. *American Journal of Medical Sciences*, 251, 600-616.

Doty, R.W. (1968) Neural organization of deglutition. In Code, C.F. (Ed.) *Handbook of Physiology. Alimentary Canal*. Section VI. Vol. IV. American Physiological Society. Washington, DC.

Doty, R.W., & Bosma, J.F. (1956) An electromyographic analysis of reflex deglutition. *Journal of Neurophysiology*, 19, 44.

Douse, M.A., & Duffin, J. (1993) Axonal projections and synaptic connections of C5 segment expiratory interneurons in the cat. *Journal of Physiology (London)*, 470, 431.

Draper, M.H., Ladefoged, P., & Whitteridge, D. (1959) Respiratory muscles in speech. *Journal of Speech and Hearing Research*, 2, 16-27.

Duron, B. (1973) Postural and ventilatory functions of intercostal muscles. *Acta Neurobiol. Exp.*, 33, 355.

Duron, B., & Marlot, D. (1980) Intercostal and diaphragmatic electrical activity during wakefulness and sleep in normal unrestrained adult cats. *Sleep*, 3(3/4), 269.

Duron, B., & Rose, D. (1997) The intercostal muscles. In Miller, A.D., Bianchi, A.L., & Bishop, B.P. (Eds.) *Neural Control of the Respiratory Muscles*. CRC Press: Boca Raton, FL.

Eadie, M.J., & Tyrer, J.H. (1965a) Alimentary disorder in Parkinsonism. *Australian Annals of Medicine*, 14, 13-22.

Eadie, M.J., & Tyrer, J.H. (1965b) Radiological abnormalities of the upper part of the alimentary tract in Parkinsonism. *Australian Annals of Medicine*, 14, 23-27.

Ebihara, S., Saito, H., Kanda, A., Nakajoh, M., Takahashi, H., Arai, H., & Sasaki, H. (2003) Impaired efficacy of cough in patients with Parkinson disease. *Chest*, *124(3)*, 1009-15.

Enoka, R.M. (1988) Muscle strength and its development. New perspectives. *Sports Medicine*, 6(3), 146-68.

Errchidi, S., Monteau, R., & Hilaire, G. (1991) Noradrenergic modulation of the medullary respiratory rhythm generator in the newborn rat: an in vitro study. *Journal of Physiology (London)*, 443, 477.

Ezure, K., Oku Y., & Tanaka I. (1993) Location and axonal projection of one type of swallowing interneurons in cat medulla *Brain Research* 632, 216

Fattapposta F., Pierelli F., My F., Mostarda M., Del Monte S., Parisi L., Serrao M., Morocutti A., & Amabile G. (2002) L dopa effects on preprogramming and control activity in a skilled motor act in Parkinson's disease. *Clinical Neurophysiology* 113(2) 243-53

Fedorko L., Connelly C.A. & Remmers J.E. (1987) Neurotransmitters mediating synaptic inhibition of phrenic motoneurons. In Sieck G.C., Gandevia, S.C., & Cameron W.E. (Eds.) *Respiratory Muscles and their Neuromotor Control* Alan R. Liss New York

Fernandez H.H., & LaPane, K.L. (2002) Predictors of mortality among nursing home residents with a diagnosis of Parkinson's disease *Med Sci Monit, 8(4)*, 241-246

Fink, B.R. & Demarest, R.J. (1978) X-ray studies on bronchial movements *American Journal of Anatomy* 35, 303-320

Florez, J., Delgado G. & Armijo J.A. (1972) Adrenergic and serotonergic mechanisms in morphine-induced respiratory depression. *Psychopharmacologia*, 24 258

Fontana, G.A., Pantaleo T., Lavorini, F., Benvenuti F., Gangemi S. (1998) Defective motor control of coughing in Parkinson's disease *American Journal of Respiration and Critical Care Medicine*, 158, 458-464

Forno, L.S. (1981) Pathology of Parkinson's disease. In Marsden, D. & Fahn, S. (Eds.) *Neurology II Movement Disorders* Butterworth. Stoneham, MA

Foutz, A.S., Pierrefiche, O. & Denavit-Saubie M. (1994) Combined blockade of NMDA and non-NMDA receptors produces respiratory arrest in the adult cat. *NeuroReport*, 5, 481

Frysinger, R.C. & Harper, R.M. (1986) Cardiac and respiratory relationships with neural discharge in the anterior cingulated cortex during sleep-waking states *Experimental Neurology* 94, 247

Gestreau, C., Milano, S., Bianchi, A.L., & Grelot, L. (1996) Activity of dorsal respiratory group inspiratory neurons during laryngeal induced fictive coughing and swallowing in decerebrate cats *Experimental Brain Research* 108, 297

Gibberd, F.B., Page, N.G., Spencer, K.M., Kinnear, E. & Hawksworth, J.B. (1981) Controlled trial of physiotherapy and occupational therapy for Parkinson's disease. *British Medical Journal* 282(6271) 1196

Glassman, S.G. (1998) Pulmonary rehabilitation in the acute inpatient rehabilitation

hospital *Respiratory Care and Clinical Nursing in America* 4(1) 47 57

Glendinning D.S Enoka, R M. (1994) Motor unit behavior in Parkinson s disease *Physical Therapy*. 74(1), 61-70

Gorell, J M Johnson, C C. & Rybicki, B A. (1994) Parkinson s disease and its comorbid disorders an analysis of Michigan mortality data, 1970 to 1990 *Neurology 44 (10)* 1856-1858

Gosselink R., Kovacs, L., Ketelaer, P Carton, H. & Decramer M (2000) Respiratory muscle weakness and respiratory muscle training in severely disabled multiple sclerosis patients *Archives of Physical Medicine and Rehabilitation, 81(6)*, 747-751

Grillner, S Wallen P., Dale, N., Brodin L., Buchanan, J. & Hill R (1987) Transmitters, membrane properties and network circuitry in the control of locomotion in lamprey *Trnds Neurosc.*, 10, 34, 1987

Halliday D.M Conway, B A Farmer S.F. & Rosenberg J R. (1998) Using electroencephalography to study functional coupling between cortical activity and electromyograms during voluntary contractions in humans *Neurosci Letters*, 241(1) 5 8

Harper R M. (1997). Higher brain areas involved in respiratory control In Miller, A D Bianchi A L., & Bishop B P (Eds.) *Neural Control of the Respiratory Muscles* CRC Press Boca Raton, FL

Hart B (1981) The effect of age and habitual activity on the fractionated components of resisted and unresisted response time *Medicine and Science in Sports and Exercise 13* 78

Henneman E. (1957) Relation between size of neurons and their susceptibility to discharge *Science* 126,1345

Herer B., Arnulf I & Housset B (2001) Effects of levodopa on pulmonary function in Parkinson's disease *Chest* 119(2) 387-93

Heyes, M.P , Garnett E.S. & Coates G (1986) Nigrostriatal dopaminergic activity is increased during exhaustive exercise stress in rats *Life Sciences*, 42(16), 1537-42

Hickson, R (1980) Interference of strength development by simultaneously training for strength and endurance. *European Journal of Applied Physiology* 45 255-63

Hilaire, G & Monteau, R. (1997) Brainstem and spinal control of respiratory muscles during breathing In Miller A D , Bianchi, A. L., & Bishop, B P (Eds) *Neural Control of the Respiratory Muscles* CRC Press Boca Raton FL.

Hiss, S., Treole, K., & Stuart, A. (2001). Effects of age, gender, bolus volume, and trial on swallowing apnea duration and swallow/respiratory phase relationships of normal adults. *Dysphagia, 16*, 128-135.

Hixon, T.J. (1973). Kinematics of the chest wall during speech production: Volume displacements of the rib cage, abdomen, and lung. *Journal of Speech & Hearing Research, 16*(1), 78-115.

Hixon, T.J. (1991). Respiratory function in speech. In Hixon, T.J. *Respiratory Function in Speech and Song*. Singular Publishing Group, Inc. San Diego, CA.

Hixon, T.J., Mead, J., & Goldman, M.D. (1976). Dynamics of the chest wall during speech production: Function of the thorax, rib cage, diaphragm, and abdomen. *Journal of Speech & Hearing Research, 19*(2), 297-356.

Hixon, T.J., & Weismer, G. (1995). Perspectives on the Edinburgh study of speech breathing. *Journal of Speech & Hearing Research, 38*(1), 42-60.

Hoffman-Ruddy, B., Sepienza, C., Brown, S., Davenport, P., & Martin, D. (2001). The effect of expiratory muscle training in high risk performers. A poster presentation in the American Speech Language Hearing Association Annual Convention.

Hoehn, M., & Yahr, M. (1967). Parkinsonism: Onset, progression and mortality. *Neurology, 17*, 427.

Hoit, J.D., & Hixon, T.J. (1986). Body type and speech breathing. *Journal of Speech and Hearing Research, 29*, 313-324.

Hoit, J.D., & Hixon, T.J. (1987). Age and speech breathing. *Journal of Speech and Hearing Research, 30*, 351-366.

Hoit, J.D., Hixon, T.J., Watson, P.J., & Morgan, W.J. (1990). Speech breathing in children and adolescents. *Journal of Speech and Hearing Research, 33*, 51-69.

Holloway, J., & Baeche, T. (1990). Strength training for female athletes: A review of selected aspects. *Sports Medicine, 9*, 216-28.

Hovestadt, A., Bogaard, J.M., Meerwaldt, J.D., van der Meché, F.G., & Stigt, J. (1989). Pulmonary function in Parkinson's disease. *Journal of Neurology,Neurosurgery, and Psychiatry, 52*(3), 329-333.

Hsiao, C., Lahiri, S., & Mokashi, A. (1989). Peripheral and central dopamine receptors in respiratory control. *Respiratory Physiology, 76*, 327.

Issa, F.Q., & Porostocky, S. (1994). Effect of continuous swallowing on respiration.

Respiratory Physiology 95 181

Izquierdo-Alonso, J.L., Jimenez Jimenez F.J., Cabrera-Valdivia, F., Mansilla-Lesmes, M. (1994) Airway dysfunction in patients with Parkinson s disease *Lung* 172 47 55

Jacquin, T., Denavit-Saubié, M., & Champagnat J (1989) Substance P and serotonin mutually reverse their excitatory effects in the rat nucleus tractus solitarius *Brain Research*, 502, 214

Jean A (1984) Control of the central swallowing program by inputs from the peripheral receptors A review *Journal of the Autonomic Nervous System*, 10, 225

Jean, A (1990) Brainstem control of swallowing localization and organization of the central pattern generator for swallowing In Taylor, A (Ed.), *Neurophysiology of the Jaws and Teeth* Macmillan London

Jean A & Car A (1979) Inputs to the swallowing medullary neurons from the peripheral afferent fibers and the swallowing cortical area *Brain Research* 178, 567

Jean A., Car, A., & Kessler, J (1997) Brainstem organization of swallowing and its interaction with respiration In Miller, A D., Bianchi, A L., & Bishop, B P (Eds.) *Neural Control of the Respiratory Muscles* CRC Press Boca Raton, FL

Johnson, M T., Kipnis, A N., Lee, M.C., Loewenson, R B., Ebner, T.J (1991) Modulation of the stretch reflex during volitional sinusoidal tracking in Parkinson s disease *Brain*, 114 (Pt 1B), 443 60

Kahrilas, P.J., Lin, S., Chen, J., Logemann, J.A (1996) Oropharyngeal accommodation to swallow volume. *Gastroenterology* 111(2) 297 306

Kahrilas, P.J, Lin, S., Logemann, J.A., Ergun, G.A., & Facchini, F (1993) Deglutitive tongue action volume accommodation and bolus propulsion *Gastroenterology* 104(1) 152 62.

Kahrilas, P.J., & Logemann, J.A (1993) Volume accommodation during swallowing *Dysphagia*, 8(3) 259-65

Karlsson, S., Persson, M., & Johnels, B (1992) Levodopa induced ON-OFF motor fluctuations in Parkinson's disease related to rhythmical masticatory jaw movements. *Journal of Neurology, Neurosurgery, & Psychiatry* 55(4), 304-7

Karlsson, J.A., Sant Ambrogio, G., & Widdicombe, J (1988) Afferent neural pathways in cough and reflex bronchoconstriction *Journal of Applied Physiology* 65 1007

Karvonen J, Saarelainen S, & Nieminen M.M (1994) Measurement of respiratory muscle forces based on maximal inspiratory and expiratory pressures, *Respiration*, 61(1) 28-31.

Kent, R.D (1997) *The Speech Sciences* Singular Publishing Group Inc San Diego, CA.

Kessler, J P (1993) Involvement of excitatory amino acids in the activity of swallowing related neurons of the ventro-lateral medulla. *Brain Research*, 603 353

Kessler, J P., & Jean, A (1985) Identification of the medullary swallowing regions in the rat. *Experimental Brain Research*, 57 256

Kessler J P., & Jean, A. (1991). Evidence that activation of N-methyl D-asparate (NMDA) and non NMDA receptors within the nucleus tractus solitarii triggers swallowing. *European Journal of Pharmacology* 201, 59

Kessler, J.P , Cherkaoui, N , Catalin, D , & Jean, A (1990) Swallowing responses induced by microinjections of glutamate and glutamate agonists into the nucleus tractus solitarius of ketamine-anaesthetized rats *Experimental Brain Research*, 83 151

Kirkwood, P A , Schmid, K , & Sears, T.A (1993) Functional identities of thoracic respiratory interneurons in the cat *Journal of Physiology (London)* 46 667

Koizumi, H, Kogo, M, & Matsuya, T (1996) Coordination between palatal and laryngeal muscle activities in response to rebreathing and lung inflation *Cleft Palate Craniofacial Journal* 33(6) 459-462.

Körkkö, P (1998) Effects of lung volume on vertical larynx position during phonation *Journal of Voice*, 12 2 159

Korpas, J , & Tomori, Z (1979) *Cough and other respiratory reflexes* S Karger Inc Basel Switzerland

Köseoğlu, F , & Tomruk, S (2001) Rehabilitation of the respiratory dysfunction in Parkinson's disease. *Functional Neurology* 16 267-276

Kuhlemeier, K.V , Palmer, J.B., & Rosenberg, D (2001) Effect of liquid bolus consistency and delivery method on aspiration and pharyngeal retention in dysphagia patients *Dysphagia*, 16(2), 119 22

Kuna, S T , & Vanoye, C R (1994) Laryngeal response during forced vital capacity maneuvers in normal adult humans *American Journal of Respiration and Critical*

Care Medicine 150 729 734

Labuszewski T., & Lidsky T I. (1979) Basal gangha influence on brainstem trigeminal neurons *Experimental Neurology*, 65 471-477

Larson, C R Yajima Y & Ko, P (1994) Modification in activity of medullary respiratory related neurons for vocalization and swallowing *Journal of Neurophysiology*, 71 2294

Laskowski M B & Sanes, J R (1987) Topographic mapping of motor pools onto skeletal muscles *Journal of Neuroscience*, 7 252 1987

Lazarus C L. Logemann J A Rademaker A W Kahrilas P J Pajak, T Lazar, R. & Halper A. (1993) Effects of bolus volume, viscosity and repeated swallows in nonstroke subjects and stroke patients *Arch. Phys Med Rehabil* 74(10), 1066-70

Leith, D.E., Butler J.P , Sneddon S L., & Bratn J D (1986) Cough In Macklem P T & Mead J (Eds) *Handbook of Physiology Section 3 Vol 1* American Physiological Society Washington DC

Leonard R.J , Kendall K.A McKenzie, S Goncalves M I & Walker, A (2000) Structural displacements in normal swallowing A videofluoroscopic study *Dysphagia*, 15(3) 146-52

Leopold, N A , & Kagel M C (1996) Prepharyngeal dysphagia in Parkinson s disease *Dysphagia* 11, 14-22

Leopold, N A & Kagel M C (1997) Pharyngo-esophageal dysphagia in Parkinson's disease. *Dysphagia*, 12 11-18

Lieberman A N Horowitz L. Redmond, P Redmond, L. Lieberman, I., & Leibowitz M (1980) Dysphagia in Parkinson's disease. *American Journal of Gastroenterology* 74 157 160

Logemann (1998) *Evaluation and Treatment of Swallowing Disorders.* Pro-ed, Austin TX.

Logemann J A. Blonsky E.R & Boshes B (1975) Editorial Dysphagia in Parkinsonism *JAMA*. 6 231(1) 69 70

Lowe, A. A (1980) The neural regulation of tongue movements *Prog Neurobiol*, 15(4) 295 344

Macefield G & Gandevia, S C (1992) Peripheral and central delays in the cortical projections from human trutical muscles rapid central transmission of

proprioceptive input from the hand but not the trunk. *Brain*, 115(1), 123

MacRae, P G., Spirduso, W W., Cartee, G D., Farrar, R P., & Wilcox, R E. (1987) Endurance training effects on striatal D2 dopamine receptor binding and striatal dopamine metabolite levels. *Neuroscience Letters*, 79(1-2), 138-44

Marks, R. (2000) *Designing a Research Project*. Renaissance Printing: Gainesville, FL.

Marks, J D., Frysinger, R C., & Harper, R M. (1987) State-dependent respiratory depression elicited by stimulation of the orbital frontal cortex. *Experimental Neurology*, 95, 714

Marsden, C.D. (1994) Parkinson's disease. *Journal of Neurology, Neurosurgery and Psychiatry*, 57, 672-681

Martin, B.J., Logemann, J.A., Shaker, R., & Dodds, W.J. (1994) Coordination between respiration and swallowing: respiratory phase relationship and temporal integration. *Journal of Applied Physiology*, 72, 714

Marttila, R.J. (1983) Diagnosis and epidemiology of Parkinson's disease. *Acta Neurol. Scand.*, 95, 9-17

McArdle, W., Katch, F., & Katch, V. (1996) *Exercise Physiology: Energy, Nutrition, and Human Performance*. Baltimore: Williams & Wilkins

McAuley, J H., Rothwell, J C., & Marsden, C D. (1997) Frequency peaks of tremor, muscle vibration and electromyographic activity at 10 Hz, 20 Hz and 40 Hz during human finger muscle contraction may reflect rhythmicities of central neural firing. *Experimental Brain Research*, 114(3), 525-41

McCrimmon, D R., Dempsey, J A., & Olson, E B. (1983) Effect of catecholamine depletion on ventilatory control in unanesthetized normoxic and hypoxic rats. *Journal of Applied Physiology*, 55, 522

McHorney, C A., Bricker, D E., Kramer, A E., Rosenbek, J C., Robbins, J., Chignell, K A., Logemann, J A., & Clarke, C. (2000) The SWAL-QOL outcomes tool for oropharyngeal dysphagia in adults: I. Conceptual foundation and item development. *Dysphagia*, 15(3), 115-21

McHorney, C A., Bricker, D E., Robbins, J., Kramer, A E., Rosenbek, J C., & Chignell, K A. (2000) The SWAL-QOL outcomes tool for oropharyngeal dysphagia in adults: II. Item reduction and preliminary scaling. *Dysphagia*, 15(3), 122-33

Meier-Ewert, H K., Van Herwaarden, M A., Gideon, R M., Castell, J A., Achem, S., Castell, D O. (2001) Effect of age on differences in upper esophageal sphincter

and pharynx pressures between patients with dysphagia and control subjects *American Journal of Gastroenterology* 96(1) 35-40

Melcon M.C , Hoit J.D & Hixon T.J (1989) Age and laryngeal airway resistance during vowel production *Journal of Speech and Hearing Disorders* 54 282-286

Merril E.G , & Fedorko L. (1984) Monosynaptic inhibition of phrenic motoneurons a long descending projection from Bötzinger neurons. *Journal of Neuroscience*, 4, 2350

Metler C A & Vannatta R A (2001) *Advanced and Multivariate Statistical Methods Practical Application an Interpretation* Pyrczak Publishing Los Angeles CA

Mettar E.J & Hanson, W R (1986) Clinical and acoustical variability in hypokinetic dysarthria *Journal of Communication Disorders, 19* 347-366

Miller A.D. Bianchi A.L. & Bishop B P (1997) Overview of the neural contral of the respiratory muscles In Miller, A D Bianchi A L. & Bishop B P (Eds) *Neural Control of the Respiratory Muscles* CRC Press Boca Raton FL.

Miller A D Ezure K., & Suzuki I. (1985) Control of abdominal muscles by brain stem respiratory neurons in the cat *Journal of Neurophysiology*, 54, 155

Miller A.J (1982) Deglutition, *Physiological Review* 62 129-184

Mizuno M (1991) Human respiratory muscles Fibre morphology and capillary supply *European Respiratory Journal* 4(5) 587 601

Morin Surun M.P Boudinot E Gacel, G Champagnat, J , Roques B P & Denavit-Sanbié M (1984) Different effects of delta and mu opiates agonists on respiration. *European Journal of Pharmacology* 98 235

Morin Surun M.P Gacel, G., Champagnat, J Denavit Saubié, M & Roques B P (1984) Pharmacological identification of delta and mu opiate receptors on bulbar respiratory neurons *European Journal of Pharmacology* 98 241

Montani T & deVries, H A (1979) Neural factors versus hypertrophy in the time course of muscle strength gain *American Journal of Physical Medicine* 58(3) 115 30

Montani T & deVries H A (1980) Potential for gross muscle hypertrophy in older men *Journal of Gerontology* 35(5) 672-82

Morrell R.M. (1992) Neurologic disorders of swallowing In Groher M E. (Ed.),

Dysphagia Diagnosis and management Butterworth Heinemann Stoneham MA

Mueller, P.B (1971) Parkinson's disease Motor speech behavior in a selected group of patients *Folia Phoniatrica, 23* 333 345

Mueller R.A., Lundberg, d B A Breese, G R Hedner, J Hedner, T , & Jonason, J (1982) The neuropharmacology of respiratory control *Pharmacological Review* 34 255

Monschauser, P.E. Mader, M.J , Ahuja, A , & Jacobs, L (1991) Selective paralysis of voluntary but not limically influenced antomatic respiration *Archives of Neurology* 48 1190

Nagaya, M , Kachi T. Yamada, T. & Igata, A (1998) Videofluorographic study of swallowing in Parkinson s disease *Dysphagia,* 13, 95-100

Nakano, K.K , Bass H , & Tyler, H R (1972) Levodopa in Parkinson's disease *Archives of Internal Medicine* 130 346-348

Neas, L.M., & Schwartz J (1998) Pulmonary function level as predictors of mortality in a national sample of US adults *Am J Epidemiol* 147(11) 1011-8

Netsell R. Daniel, B. & Celesia, G G (1975) Acceleration and weakness in Parkinsonian dysarthria. *Journal of Speech and Hearing Disorders* 40 170-177

Neu, H C., Connolly J.J. Schwentley F W. Ladwig, H.A , & Brody A W (1967) Obstructive respiratory dysfunction in Parkinsonian patients *American Review of Respiratory Disease* 96 33-47

Nishino, T , Yonezawa T , & Honda, Y (1985) Effects of swallowing on the pattern of continuous respiration in human adults *American Review of Respiratory Disease,* 132, 1219

Obenour, W H. Stevens, P M , Cohen, A A , & McCutchen J J (1972) The causes of abnormal pulmonary function in Parkinson's disease *American Review of Respiratory Disease* 105 382-387

Oku Y , Tanaka I & Ezure, K (1994) Activity of bulbar respiratory neurons during fictive coughing and swallowing in the decerebrate cat. *Journal of Physiology,* 480, 309

Olanow C.W & Koller, W C (1998) An algorithm (decision tree) for the management of Parkinson's disease Treatment guidelines *Neurology* 50 (3, Suppl 3) S1-57

Olanow C W & Koller, W C (2001) An algorithm (decision tree) for the management

of Parkinson's disease Treatment guidelines *Neurology* 56 (11, Suppl 5), S1 88

O Shea, J. & Wagner J (1981) Power weight training in the female athlete *Physician and Sports Medicine* 9 109 14

Paulson G.D. & Tafrate R H (1970) Some "minor" aspects of Parkinsonism, especially pulmonary function *Neurology* 20(12), 14-17

Pepper, P V., & Goldstein M K (1999) Postoperative complications in Parkinson's disease *J Am Geriatr Soc*, 47(8) 967 972.

Perlman, A.L. Palmer P M McCulloch T M Vandaele, D.J (1999) Electromyographic activity from human laryngeal pharyngeal and submental muscles during swallowing *Journal of Applied Physiology* 86(5), 1663 9

Pinnington, L.L., Muhiddin, K A., Ellis, R E., & Playford, E.D (2000). Non-invasive assessment of swallowing and respiration in Parkinson's disease *Journal of Neurology* 247(10) 773 7

Powers S K & Howley E.T (2001) *Exercise Physiology Theory and Application to Fitness and Performance* McGraw-Hill New York NY

Preiksaitis H G Mayrand S Robins K. Diamant N E. (1992) Coordination of respiration and swallowing Effect of bolus volume in normal adults *American Journal of Physiology* 263(3 Pt 2) R624-30

Preiksaitis H G., & Mills C A (1996) Coordination of breathing and swallowing Effects of bolus consistency and presentation in normal adults. *Journal of Applied Physiology* 81(4), 1707 1714

Remple, O., Pierrefiche O., & Denavit-Saubié M (1993) Effects of serotonin and substance P on bulbar respiratory neurons in vivo. *Brain Research*, 622 185

Ramsay S C Adams L. Murphy K., Corfield D.R., Grootoonk S Bailey D L., Frackowiak R.S & Guz A (1993) Regional cerebral blood flow during volitional expiration in man a comparison with volitional inspiration *Journal of Physiology* 461 85

Randa, R. J & Maaclean P D (1981) Vagal elicitation of respiratory type and other unit responses in basal limbic structures of squirrel monkeys *Brain Research*, 213-45

Reimers-Neils L., Logemann J & Larsen C (1994) Viscosity effects on EMG activity in normal swallow *Dysphagia* 9(2), 101-6

Remmers, J.E. (1973). Extra-segmental reflexes derived from intercostal afferents: Phrenic and laryngeal responses. *Journal of Physiology (London)*, 233, 45.

Richter, D.W., Ballantyne, D., & Remmers, J.E. (1986). How is the respiratory rhythm generated? *News Physiol. Sci.*, 1, 109.

Robbins, J.A., Logemann, J.A., & Kirschner, H.S. (1986). Swallowing and speech production in Parkinson's disease. *Annals of Neurology*, 19, 283-287.

Robey, R.R., & Schultz, M.C. (1998). A model for conducting clinical-outcome research: An adaptation of the standard protocol for use in aphasiology. *Aphasiology*, 12(9), 787-810.

Rosenbek, J.C., Robbins, J.A., Roecker, E.B., Coyle, J.L., & Wood, J.L. (1996). A penetration-aspiration scale. *Dysphagia*, 11(2), 93-98.

Russell, N.K., & Stathopoulos, E. (1988). Lung volume changes in children and adults during speech production. *Journal of Speech and Hearing Research*, 31, 146-155.

Sale, D.G. (1987). Influence of exercise and training on motor unit activation. *Exercise and Sport Sciences Reviews*, 15, 95-151.

Sale, D.G. (1988). Neural adaptation to resistance training. *Medical Sciences and Sports Exercise*, 20, 135-145.

Salenius, S., Avikainen, S., Kaakkola, S., Hari, R., & Brown, P. (2002). Defective cortical drive to muscle in Parkinson's disease and its improvement with levodopa. *Brain*, 125(Pt 3), 491-500.

Sales, N., Riche, D., Roques, E.P., & Denavit-Saubié, M. (1985). Localization of mu and alpha opioid receptors in cat respiratory areas: An autoradiographic study. *Brain Research*, 344, 382.

Sapienza, C.M. (2002). Improvement of Speech Production in Individuals with Spinal Cord Injury. Presented at the American Speech-Language Hearing Association, Atlanta, GA, November.

Sapienza, C.M., Davenport, P.D., & Martin, A.D. (2002). Expiratory muscle training increases pressure support in high school band students. *Journal of Voice*, 16(4), 495-501.

Sapienza, C.M., Hoffman Ruddy, B., Davenport, P., Martin, D., & Lehman, J. (2001). Acoustic and physiological characteristics of high risk vocal performers following expiratory pressure threshold training. *In proceedings for the 17th International Congress on Acoustics*. Sept., Rome, Italy.

Scandalis, T A , Bosak, A., Berliner, J C., Helman, L.L., & Wells, M R. (2001) Resistance training and gait function in patients with Parkinson s disease *American Journal of Physical Medicine and Rehabilitation* 80(1), 38-43

Schiermer, S , Schafer, D., Schafer, T , Greulich, W., & Schlafke, M E (2001) Breathing and locomotion in patients with Parkinson s disease *Pflugers Archiv European Journal of Physiology* 443(1) 67-71

Schmid, K., Böhmer, G., & Gebauer, K. (1991) Glycine receptor-mediated fast synaptic inhibition in the brainstem respiratory system *Respiratory Physiology*, 84, 351

Schneider, J.S , Diamond, S G , & Markham, C H (1986) Deficits in orofacial sensorimotor function in Parkinson's disease *Annals of Neurology* 19, 275-282.

Schunemann, H.J , Dorn, J., Grant, B J , Winkelstein, W Jr , & Trevisan, M (2000) Pulmonary function is a long-term predictor of mortality in the general population 29-year follow-up of the Buffalo Health Study *Chest*, 118(3) 656-64

Schwartz, J D , Katz, S.A. Fegley, R W , & Tockman, M S (1988) Analysis of spirometric data from a national sample of healthy 6- to 24-year-olds (NHANES II) *Am. Rev Respir Dis* 138(6), 1405-14

Shannon, R., Baoler, D., & Lindsey, B. (1997) Neural control of coughing and sneezing. In Miller, AD Bianchi, AL, & Bishop, BP (Eds) *Neural Control of the Respiratory Muscles* CRC Press New York, NY

Sharkawi, A.E., Ramig, L., Logemann, J.A. Pauloski, B R. Rademaker, A.W., Smith, C H. et al (2002) Swallowing and voice effects of Lee Silverman Voice Treatment (LSVT) A pilot study *Journal of Neurology, Neurosurgery Psychiatry* 72 31-6

Shill, H. & Stacy, M. (1998) Respiratory function in Parkinson's disease. *Clinical Neuroscience of New York* 5(2), 131-135

Sieck, G C & Fournier, M. (1989) Diaphragm motor unit recruitment during ventilatory and nonventilatory behaviors *Journal of Applied Physiology* 66 2539

Sieck, G C & Prakash, Y.S (1997) The diaphragm muscle. In Miller, A. D., Bianchi A L & Bishop, B P (Eds) *Neural Control of the Respiratory Muscles* CRC Press Boca Raton FL.

Silbiger, M L., Pikielney, R., & Donner, M W (1967) Neuromuscular disorders affecting the pharynx Cineradiographic analysis *Investigational Radiology*, 2(6) 442-8

Singer, R B (1992) Mortality in patients with Parkinson's disease treated with dopa.

Journal of Insurance Medicine 24(2), 126-127

Smeltzer, S C., Lavieles, M H., & Cook, S D (1996) Expiratory training in multiple sclerosis. *Archives of Physical Medicine and Rehabilitation* 77(9), 909-12

Smith, J C , Ellenberger, H H, Ballanyi, K , Richter D W , & Feldman J L (1991) Pre-Bötzinger complex A brainstem region that may generate respiratory rhythm in mammals. *Science*, 254 726

Solomon N P & Hixon T J (1993) Speech breathing in Parkinson s disease *Journal of Speech and Hearing Research*, 36(2) 294-310

Speciale S G Miller J.D McMillen B A German, D C (1986) Activation of specific central dopamine pathways Locomotion and footshock. *Brain Research Bulletin* 16(1), 33 8

Sumi T (1963) The activity of brainstem respiratory neurons and spinal respiratory motoneurons during swallowing *Journal of Neurophysiology* 26, 466

Sumi T (1969) Synaptic potentials of hypoglossal motoneurons and their relation to reflex deglutition. *Japanese Journal of Physiology* 19, 68

Tell F & Bradley R (1994) Whole-cell analysis of ionic currents underlying the firing pattern of neurons in the gustatory zone of the nucleus tractus solitarii *J Neurophysiolo* 71, 479

Tell F & Jean A (1991) Activation of *N*-methyl D-aspartic receptors induces endogenous rhythmic bursting activities in nucleus tractus solitarii neurons An intracellular study on adult rat brainstem slices *European Journal of Neuroscience* 3, 1353

Tell F & Jean A (1993) Ionic bases for endogenous rhythmic patterns induced by activation of *N* methyl-D-aspartic receptors in neurons of the rat nucleus tractus solitarii *Journal of Neurophysiology*, 70 2379

Tolosa, E .& Valldeoriola F (1994) Mid-stage Parkinsonism with mild motor fluctuations *Clinical Neuropharmacology*, 17(Suppl 2), S19-S31

Troyer A (1997) Mechanics of the chest wall muscles In Miller A D Bianchi, A.L., & Bishop B P, (Eds) *Neural Control of the Respiratory Muscles*. CRC Press Boca Raton, FL.

Tzeleps, G.E., McCool F.D Friedman J H & Hoppin F G (1988) Respiratory muscle dysfunction in Parkinson s disease. *The American Review of Respiratory Disorders* 138(2) 266-271

Vincken W G Darauay C , & Cosio M (1989) Reversibility of upper airway obstruction after levodopa therapy in Parkinson's disease *Chest* 96 210-212

Vincken W G , Gauthier S G Dollfuss R E Hanson R E Darauay C M , & Cosio, M G (1984) Involvement of upper-airway muscles in extrapyramidal disorders. A cause of airway limitation *New England Journal of Medicine* 311, 438-442.

Vitek J (1997) Stereotaxic surgery and deep brain stimulation for movement disorders. In Koller, R W (Ed.) *Movement Disorders Neurologic Principles and Practice* McGraw-Hill Inc New York

Weiner, P Inzelberg R , Davidovich, A., Nisipeanu P Magadle R , Berar-Yanay, N , & Carasso R L (2002) Respiratory muscle performance and the perception of dyspnea in Parkinson's disease *Canadian Journal of Neurological Sciences* 29(1) 68-72

Wilmore J (1974) Alterations in strength body composition and anthropmetric measurements consequent to a 10-week weight training program. *Medicine and Science in Sports* 6 133-39

Winkworth A L Davis P J Adams R D , & Ellis E (1995) Breathing patterns during spontaneous speech. *Journal of Speech and Hearing Research* 38, 124-144

Winkworth A.L. Davis, P.J Ellis E., & Adams R. D (1994) Variability and consistency in speech breathing during reading Lung volumes, speech intensity, and linguistic factors *Journal of speech and Hearing Research*, 37, 535-556

Yajima Y & Larson C.R (1993) Multifunctional properties of ambiguous neurons identified electrophysiologically during vocalization in the awake monkey *Journal of Neurophysiology* 70 529

Yorkston, K M Miller R.M., & Strand, E A. (2004) *Management of Speech and Swallowing Disorders in Degenerative Diseases* Pro-ed Austin, TX

Zemlin W R (1981) The breathing mechanism In. Zemlin W R *Speech and Hearing Science* Prentice-Hall Inc Englewood Cliffs NJ

BIOGRAPHICAL SKETCH

In May of 1998 Ahmad Fans Saleem received his undergraduate degree in speech language pathology and audiology from the University of Northern Colorado in Greeley CO Upon graduation he started his graduate studies at the University of Florida in Gainesville, FL from which he received his Master of Art degree in speech-language pathology in May of 2000 Ahmad immediately pursued his doctoral degree in the field of neurogenic speech and language disorders in the Department of Communication Sciences and Disorders at the University of Florida under the direction of Dr John C Rosenbek and Dr Christine M Sapienza.

Ahmad s research focuses on the areas of neurogenic speech and language disorders. He was involved in protocols investigating the genatric behavior in either the normally aging or impaired populations Currently he is involved in several investigations to describe the speech of patients with Parkinson's disease and some other movement disorders Moreover, he is actively participating in investigations of the effects of various novel and traditional therapies in the speech and swallowing of patients with various movement disorders He will graduate from the University of Florida with a Doctorate of Philosophy in May of 2005

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy

John C. Rosenbek, Chair
Clinical Professor of Communication Sciences and Disorders

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy

Christine M. Sapienza Cochair
Professor of Communication Sciences and Disorders

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy

Paul Davenport
Professor of Veterinary Medicine

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate in scope and quality as a dissertation for the degree of Doctor of Philosophy

Rahul Shrivastav
Assistant Professor of Communication Sciences and Disorders

This dissertation was submitted to the Graduate Faculty of the Department of Communication Sciences and Disorders in the College of Liberal Arts and Sciences and the Graduate School and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy

May 2005

Dean, Graduate School